SCIENTIFIC DIALOGUES,

INTENDED FOR THE

INSTRUCTION AND ENTERTAINMENT

OF

YOUNG PEOPLE:

IN WHICH

THE FIRST PRINCIPLES

OF

Natural and Experimental Philosophy

ARE FULLY EXPLAINED.

VOL. I.

OF MECHANICS.

"Conversation, with the habit of explaining the meaning of words
"and the structure of common domestic implements to children, is
"the sure and effectual method of preparing the mind for the ac-
"quirement of science." *Edgeworth's Practical Education.*

BY THE REV. J. JOYCE.

NEW EDITION CORRECTED AND IMPROVED.

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fully engaged at a very early period of life, and which are of acknowledged importance in the pursuits of every well educated youth.

In perusing this little work you must bear in your minds, that it is not intended for proficients in philosophical knowledge, but for noviciates in science:—not for yourselves in the present advanced stage of your progress, but for those young persons who are unacquaintd with the rudiments of natural and experimental philosophy.

I am too well acquainted with the excellence of your dispositions to suppose it necessary for me to apologize for laying before you a work that has no extraordinary claim to your acceptance. You will, I am sure, appreciate its value, not so much by its intrinsic contents, as by the good-will with which it is presented.

Before I conclude this short address, permit me to say, that my own happiness will ever be much augmented, by the assurance of the happiness and distinguished usefulness of those with whom I have spent so many years of my life, and to whose permanent interest, I am sure, you will acknowledge I have never been inattentive.

Sincerely wishing you, Gentlemen, all the felicity

which the honourable exercise of distinguished talents and virtuous minds can confer upon the possessors,

I subscribe myself
Your very affectionate Friend
And obedient Servant,
THE AUTHOR.

CLAPTON, MAY, 1800.

PREFACE.

THE Author of these little volumes feels himself extremely happy in the opportunity which this publication affords him of acknowledging the obligations he is under to the authors of "Practical Education," for the pleasure and instruction which he has derived from that valuable work. To this he is solely indebted for the idea of writing on the subject of Natural Philosophy for the use of children. How far his plan corresponds with that suggested by Mr. Edgeworth in his chapter on Mechanics, must be left with a candid public to decide.

The Author conceives at least, he shall be justified in asserting, that no introduction to natural and experimental philosophy has been attempted in a method so familiar and easy as that which he now offers to the public:—none which appears to him so properly adapted to the capacities of young people of ten or eleven years of age, a period of life, which, *from the* Author's own experience, *he is confident, is by* no means too early to induce

"of much service to those who are not famili
"acquainted with the technical language in wh
"they are delivered.*"

It is presumed that an attentive perusal of th
dialogues, in which the principal and most comn
terms of science are carefully explained and ill
trated, by a variety of familiar examples, will
the means of obviating this objection, with resp
to persons who may be desirous of attending th
public philosophical lectures to which the inha
tants of the metropolis have almost constant acc

* Mr. Edgeworth's chapter on Mechanics should be recommen
to the attention of the reader, but the Author feels unwillin
refer to a part of a work, the whole of which deserves the careful
rusal of all persons engaged in the education of youth.

CONVERSATION I.

INTRODUCTION.

FATHER—CHARLES—EMMA.

CHARLES. Father you told sister Emma and me, that, after we had finished the "*Evenings at Home*," you would explain to us some of the principles of natural philosophy: you will begin this morning?

Father. Yes, I am quite at leisure; and, I shall indeed at all times take a delight in communicating to you the elements of useful knowledge; and the more so in proportion to the desire which you have of collecting and storing those facts that may enable you to understand the operations of nature, as well as the works of ingenious artists. These, I trust, will lead *you*, insensibly, to admire *the wisdom* and goodness by means of whi

the whole system of the universe is constructed and supported.

Emma. But can philosophy be comprehended by children so young as we are? I thought that it had been the business of men, and of old men too.

Father. Philosophy is a word which in its original sense signifies only a love or desire of wisdom; and you will not allow that you and your brother are too young to wish for knowledge.

Emma. So far from it, that the more knowledge I get, the better I seem to like it; and the number of new ideas which, with a little of your assistance, I have obtained from the "*Evenings at Home*," and the great pleasure which I have received from the perusal of these volumes, will I am sure, excite me to read them again and again.

Father. You will find very little in the introductory parts of natural and experimental philosophy, that requires much more of your attention than many parts of that work which you have been so delighted.

cs. But in some books of natural phi-
, which I have occasionally looked
umber of new and uncommon words
rplexed me; I have also seen refer-
› figures by means of large letters
ll, the use of which I did not com-
.

r. It is frequently a dangerous prac-
young minds to dip into subjects
hey are prepared, by some previous
lge, to enter upon them; since it
ate a distaste for the most interest-
cs. Thus those books which you
d with so much pleasure would not
forded you the smallest entertain-
few years ago, when you must have
t almost every word in each page.
ıe sort of disgust will naturally be felt
ons who attempt to read works of
before the leading terms are explain-
understood. The word *angle* is con-
recurring in subjects of this sort, do
w what an angle is?

a. I do not think I do; will you
what it means?

Father. An *angle* is made by the op
of two straight* lines. In this figure (
1. Fig. 1.) there are two straight lin
and CB meeting at the point B, and the
ing made by them is called an angle.

Charles. Whether that be small or
is it still called an angle?

Father. It is; your drawing comp
may familiarize to your mind the idea
angle; the lines in this figure will
represent the legs of the compasses, an
point B the joint upon which they mo
turn. Now you may open the legs t
distance you please, even so far that
shall form one straight line; in that
tion only they do *not* form an angle
every other situation an angle is ma
the opening of these legs, and the an
said to be greater or less, as that open
greater or less.

Emma. Are not some angles called
angles?

Father. Angles are either *right*, *acu*

---

ght lines, in works of science, are usu
right lines.

obtuse. When the line AB (Plate 1. Fig. 2.) meets another line DC, in such a manner as to make the angles ABD and ABC equal to one another, then those angles are called *right* angles. And the line AB is said to be perpendicular to DC. Hence to be perpendicular to, or to make *right* angles with a line, means one and the same thing.

Charles. Does it signify how you call the letters of an angle?

Father. It is usual to call every angle by three letters, and that at the angular point must be always the middle letter of the three. There are cases, however, where an angle may be denominated by a single letter, as in figures 1 and 3, the angle ABC may be called simply the angle B, for in these figures there is no danger of mistake, because there is but a single angle at the point B.

Charles. I understand this, for if in the second figure I were to describe the angle by the letter B only, you would not know whether I meant, the angle ABC or ABD.

Father. That is the precise reason why

it is necessary in most descriptions to make use of three letters. An *acute* angle (Fig. 1.) ABC is less than a right angle; and an *obtuse* angle (Fig. 3.) ABC is greater than a right angle.

Emma. You see the reason now, Charles, why letters are placed against or by the figures, which puzzled you before.

Charles. I do, they are intended to distinguish the separate parts of each, in order to render the description of them easier both to the author and the reader.

Emma. What is the difference, between an angle and a triangle?

Father. An angle being made by the opening of two lines, and, as you know, that two straight lines cannot enclose a space, so a *triangle* ABC (Fig. 4.) is a space bounded by three straight lines. It takes its name from the property of containg three angles. There are various sorts of triangles, but it is not necessary to enter upon these particulars, as I do not wish to burden your memories with more technical terms than we have occasion for.

Charles. A triangle then is a space or figure containing three angles, and bounded by as many straight lines.

Father. Yes, that description will answer our present purpose.

CONVERSATION II.

Of Matter.—Of the Divisibility of Matter.

Father. Do you understand what philosophers mean when they make use of the word matter?

Emma. Are not all things which we see and feel composed of matter?

Father. Every thing which is the object of our senses is composed of matter differently modified or arranged. But in a philosophical sense *matter* is defined to be *extended*, *solid*, *inactive*, and *moveable* substance.

Charles. If by extension is meant length, breadth, and thickness, matter, undoubtedly, is an extended substance. Its solidity is also manifest by the resistance it makes to the touch.

Emma. And the other properties nobody

ill deny, for all material objects are, of iemselves, without motion ; and yet it may e readily conceived, that by the applica-on of a proper force there is no body which innot be moved. But I remember, papa, iat you told us something strange about ie divisibility of matter, which you said iight be continued without end.

Father. I did, some time ago, mention iis as a curious and interesting subject, id this is a very fit time for me to ex-ain it.

Charles. Can matter indeed be infinitely ivided, for I suppose that this is what is eant by a division without end?

Father. Difficult as this may at first ap-ar, yet I think it very capable of proof. in you conceive of a particle of matter so iall as not to have an upper and under rface?

Charles. Certainly, every portion of mat-, however minute, must have two sur-ces at least, and then I see, that it follows course that it is divisible.

Father. Your conclusion is just, and

though there may be particles of matter too small for us actually to divide, yet this arises from the imperfection of our instruments; they must nevertheless, in their nature, be divisible.

Emma. But you were to give us some remarkable instances of the minute division of matter.

Father. A few years ago a lady spun a single pound of wool into a thread 168 thousands yards long. And Mr. Boyle mentions that two grains and a half of silk was spun into a thread 300 yards in length. If a pound of silver, which, you know, contains 5760 grains, and a single grain of gold be melted together, the gold will be equally diffused through the whole silver, insomuch that if one grain of the mass be dissolved in a liquid called *Aqua Fortis*, which is diluted nitric acid, the gold will fall to the bottom. By this experiment it is evident that a grain may be divided into 5761 visible parts, for only the 5761st part of the gold is contained in a single [illegible] of the mass.

[illegible]e *gold*-beaters, whom you have seen

at work in the shops in Long-Acre, can spread a grain of gold into a leaf containing 50 square inches, and this leaf may be readily divided into 500,000 parts, each of which is visible to the naked eye: and by the help of a microscope which magnifies the area or surface of a body 100 times, 100th part of each of these becomes visible, that is, the 50 millionth part of a grain of gold will be visible, or a single grain of that metal may be divided into 50 million of visible parts. But the gold which covers the silver wire used in making what is called gold lace, is spread over a much larger surface, yet it preserves, even if examined by a microscope, an uniform appearance. It has been calculated that one grain of gold under these circumstances would cover a a surface of nearly thirty square yards.

The *natural* divisions of matter are still more surprising. In odoriferous bodies, such as camphor, musk, and asafœtida, a wonderful subtilty of parts is perceived, for though *they are perpetually* filling a *considerable space with* odoriferous particles.

yet these bodies lose but a very small part of their weight in a great length of time.

Again, it is said by those who have examined the subject with the best glasses, and whose accuracy may be relied on, that there are more animals in the milt of a single cod-fish, than there are men on the whole earth, and that a single grain of sand is larger than four millions of these animals. Now if it be admitted that these little animals are possessed of organized parts, such as a heart, stomach, muscles, veins, arteries, &c. and that they are possessed of a complete system of circulating fluids, similar to what is found in larger animals, we seem to approach to an idea of the infinite divisibility of matter. It has indeed been calculated that a particle of blood of one of these animacula is as much smaller than a globe one tenth of an inch in diameter, as that globe is smaller than the whole earth. Nevertheless, if these particles be compared with the particles of light, it is probable, that they would *be found to* exceed them in bulk as much *as mountains* do single grains of sand:

In thousand species of the insect kind!
Lost to the naked eye, so wondrous small
Were millions join'd, one grain of sand would cover all,
Yet each within its little bulk, contains
A heart which drives the torrent through its veins:
Muscles to move its limbs aright: a brain
And nerves disposed for pleasure and for pain:
Eyes to distinguish: sense whereby to know
What's good or bad; is, or is not its foe. BAKER.

I might enumerate many other instances of the same kind, but these, I doubt not, will be sufficient to convince you into what very minute parts matter is capable of being divided: and with these we will put an end to our present conversation.

CONVERSATION III.

Of the Attraction of Cohesion.

FATHER. Well my children, have you reflected upon what we last conversed about? Do you comprehend the several instances which I enumerated as examples of the minute division of matter?

Emma. Indeed the examples which you gave us very much excited my wonder and admiration, and yet from the thinness of some leaf-gold which I once had, I can readily credit all you have said on that part of the subject. But I know not how to conceive of such small animals as you described; and I am still more at a loss how to imagine that animals so minute, should possess all the properties of the larger ones, such as a heart, veins, blood, &c.

Father. I can the next bright morning, by the help of my solar microscope, show

you very distinctly, the circulation of the blood in a flea, which you may get from your little dog; and with better glasses than those of which I am possessed, the same appearance might be seen in animals still smaller than the flea, perhaps, even in those which are themselves invisible to the naked eye. But we shall converse more at large on this matter, when we come to consider the subject of optics, and the construction and uses of the solar microscope. At present we will turn our thoughts to that principle in nature, which philosophers have agreed to call gravity or attraction.

Charles. If there be no more difficulties in philosophy than we met with in our last lecture, I do not fear but that we shall, in general, be able to understand it. Are there not, papa, several kinds of gravity?

Father. Yes, there are; two of which will be sufficient for our present purpose to describe; the one is the *attraction of cohesion;* the other that of *gravitation.* The *attraction of cohesion* is that power which keeps the parts of bodies together when they

touch, and prevents them from separating, or which inclines the parts of bodies to unite, when thev are placed sufficiently near to each other.

Charles. Is it then by the attraction of cohesion that the parts of this table, or of the pen-knife, are kept together?

Father. The instances which you have selected are accurate, but you might have said the same of every other solid substance in the room, and it is in proportion to the different degrees of attraction with which different substances are affected, that some bodies are hard, others soft, tough, &c. A philosopher in Holland, almost a century ago, took great pains in ascertaining the different degrees of cohesion, which belonged to various kinds of wood, metals, and many other substances. A short account of the experiments made by M. Musschenbroek, you will hereafter find in your own language, in the second edition of Dr. Enfield's Institutes of Natural Philosophy.

Charles. You once showed me that two *leaden bullets* having a little scraped from

the surfaces, would stick together with great force; you called that, I believe, the attraction of cohesion?

Father. I did: some philosophers, who have made this experiment with great attention and accuracy, assert, that if the flat surfaces, which are presented to one another, be but a quarter of an inch in diameter, scraped very smooth, and forcibly pressed together with a twist, a weight of a hundred pounds is frequently required to separate them.

As it is by this kind of attraction that the parts of solid bodies are kept together, so when any substance is separated or broken, it is only the attraction of cohesion that is overcome in that particular part.

Emma. Then, papa, when I had the misfortune this morning at breakfast, to let my saucer slip from my hands, by which it was broken into several pieces, was it only the attraction of cohesion that was overcome by the parts of the saucer being separated by its fall on the ground?

Father. Just so; for whether you un-

luckily break the china, or cut a stick wi your knife, or melt lead over the fire, your brother sometimes does, in order make plummets; these, and a thousa other instances, which are continually o curring, are but examples in which the a hesion is overcome by the fall; the kni or the fire.

Emma. The broken saucer being hig valued by mamma, she has taken the pa to join it again with white lead, was t performed by means of the attraction of c hesion?

Father. It was, my dear, and hence y will easily learn that many operations cookery are in fact nothing more than d ferent methods of causing this attraction take place. Thus flour, by itself, has lit or nothing of this principle, but when mi with milk, or other liquids, to a pro consistency, the parts cohere strongly, a this cohesion in many instances becon still stronger, by means of the heat appl to it in boiling or baking.

Charles. You put me in mind papa,

the fable of the man blowing hot and cold: for in the instance of the *lead*, fire overcomes the attraction of cohesion; and the same power, heat, when applied to puddings, bread, &c. causes their parts to cohere more powerfully. How are we to understand this?

Father. I will endeavour to remove your difficulty. Heat expands all bodies without exception, as you shall see before we have finished our lectures. Now the fire applied to metals in order to melt them, causes such an expansion, that the particles are thrown out of the sphere, or reach of each other's attraction: whereas the heat communicated in the operations of cookery, is sufficient to expand the particles of flour, but is not enough to overcome the attraction of cohesion. Besides, your mamma will tell you that the heat of boiling would frequently disunite the parts of which her puddings are composed, if she did not take the precaution of enclosing them in a cloth, leaving them just room enough to expand without the liberty of breaking to pieces; *and the moment* they are taken from th

water, they lose their superabundant heat, and become solid.

Emma. When Ann the cook makes broth for little brother, it is the heat then which overcomes the attraction which the particles of meat have for each other, for I have seen her pour off the broth, and the meat is all in rags. But will not the heat overcome the attraction which the parts of the bones have for each other?

Father. The heat of boiling water will never effect this, but a machine was invented several years ago, by Mr. Papin, for that purpose. It is called Papin's digester, and is used in taverns, and in many large families, for the purpose of dissolving bones, as completely as a lesser degree of heat will liquefy jelly. On some future day I will show you an engraving of this machine, and explain its different parts, which are extremely simple*.

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* See Vol. IV. Conver. XIX.

CONVERSATION IV.

Of the Attraction of Cohesion.

FATHER. I will now mention some other instances of this great law of nature. If two polished plates of marble, or brass, be put together, with a little oil between them to fill up the pores in their surfaces, they will cohere so powerfully as to require a very considerable force to separate them. —Two globules of quicksilver placed very near to each other, will run together and form one large drop.—Drops of water will do the same.—Two circular pieces of cork placed upon water at about an inch distant will run together.—Balance a piece of smooth board on the end of a scale beam; then let it lie flat on water, and five or six times its own weight will be required to separate it from the water. If a small

globule of quicksilver be laid on clean paper, and a piece of glass be brought into contact with it, the mercury will adhere to it, and be drawn away from the paper. But bring a larger globule into contact with the smaller one, and it will forsake the glass, and unite with the other quicksilver.

Charles. Did not you tell me that it was by means of the attraction of cohesion, that the little tea which is generally left at the bottom of the cup instantly ascends in the sugar when thrown into it?

Father. The ascent of water or other liquids in sugar, sponge, and all porous bodies is a species of this attraction, and is called *capillary* attraction;* it is thus denominated from the property which tubes of a very small bore, scarcely larger than to admit a hair, have of causing water to stand above its level.

Charles. Is this property visible in no other tubes than those, the bores of which are so exceedingly fine?

* *From capillus,* the Latin word for hair.

Father. Yes, it is very apparent in tubes whose diameters are one tenth of an inch or more in length, but the smaller the bore, the higher the fluid rises; for it ascends, in all instances, till the weight of the column of water in the tube balances, or is equal to the attraction of the tube. By immersing tubes of different bores in a vessel of coloured water, you will see that the water rises as much higher in the smaller tube, than in the larger, as its bore is less than that of the larger. The water will rise a quarter of an inch, and there remain suspended in a tube, whose bore is about one eighth of an inch in diameter.

This kind of attraction is well illustrated, by taking (Plate 1. Fig. 5.) two pieces of glass joined together at the side BC, and kept a little open at the opposite side AD, by a small piece of cork E. In this position immerse them in a dish of coloured water, FG, and you will observe that the attraction of the glass at, and near BC, will cause the fluid to ascend to B, whereas about the parts D, it scarcely rises above the level of the water in the vessel.

Charles. I see that a curve is formed by the water.

Father. There is, and to this curve there are many curious properties belonging as you will hereafter be able to investigate for yourself.

Emma. Is it not upon the principle of the attraction of cohesion, that carpenters glue their work together?

Father. It is upon this principle that carpenters and cabinet-makers make use of glue; that braziers, tinmen, plumbers, &c. solder their metals; and that smiths unite different bars of iron by means of heat. These and a thousand other operations, of which we are continually the witnesses, depend on the same principle as that which induced your mamma to use the white lead in mending her saucer. And you ought to be told, that though white lead is frequently used as a cement for broken china, glass, and earthen ware, yet if the vessels are to be brought again into use, it is not a proper *cement, being* an active poison; besides, one *much stronger* has been discovered, I

believe, by a very able and ingenious philosopher, the late Dr. Ingenhouz, at least I had it from him several years ago; it consists simply of a mixture of quick-lime, and Glocester cheese, rendered soft by warm water, and worked up to a proper consistency.

Emma. What! do such great philosophers, as I have heard you say Dr. Ingenhouz was, attend to such trifling things as these?

Father. He was a man deeply skilled in many branches of science; and I hope that you and your brother will one day make yourselves acquainted with many of his important discoveries. But no real philosopher will consider it beneath his attention to add to the conveniences of life.

Charles. This attraction of cohesion seems to pervade the whole of nature.

Father. It does, but you will not forget that it acts only at very small distances. Some bodies indeed appear to possess a power the reverse of the attraction of cohesion.

Emma. What is that, papa?

Father. It is called repulsion. Thus water repels most bodies till they are wet. A small needle carefully placed on water will swim: flies walk upon it without wetting their feet:

> Or bathe unwet their oily forms, and dwell
> With feet repulsive on the dimpling well.
>
> DARWIN.

The drops of dew which appear in a morning on plants, particularly on cabbage plants, assume a globular form, from the mutual attraction between the particles of water; and upon examination it will be found that the drops do not touch the leaves, for they will roll off in compact bodies, which could not be the case if there subsisted any degree of attraction between the water and the leaf.

If a small thin piece of iron be laid upon quicksilver, the repulsion between the different metals will cause the surface of the quicksilver near the iron to be depressed.

The repelling force of the particles of a fluid is but small; therefore, if a fluid be divided it easily unites again. But if a glass or any hard substance be broken, the parts cannot be made to cohere without being first moistened, because the repulsion is too great to admit of a reunion.

The repelling force between water and oil is likewise so great, that it is impossible to mix them in such a manner, that they shall not separate again.

If a ball of light wood be dipped in oil, and then put into water, the water will recede so as to form a small channel around the ball.

Charles. Why do cane, steel, and many other things bear to be bent without breaking, and when set at liberty again, recover their original form?

Father. That a piece of thin steel, or cane, recovers its usual form after being bent, is owing to a certain power, called *elasticity;* which may, perhaps, arise from the particles of those bodies, though dis-

turbed, not being drawn out of each other's attraction; therefore, as soon as the force upon them ceases to act, they restore themselves to their former position.—But our half hour is expired, I must leave you.

CONVERSATION V.

Of the Attraction of Gravitation.

FATHER. We will now proceed to discuss another very important general principle in nature; the *attraction of gravitation*, or, as it is frequently termed, gravity, which is that power by which *distant* bodies tend towards each other. Of this we have perpetual instances in the falling of bodies to the earth.

Charles. Am I then to understand, that whether this marble falls from my hand; or a loose brick from the top of the house; or an apple from the tree in the orchard, that all these happen by the attraction of gravity?

Father. It is by the power which is commonly expressed under the term *gravity*, that all bodies whatever have a tendency to

the earth, and, unless supported, will fall in lines nearly perpendicular to its surface.

Emma. But are not smoke, steam, and other light bodies which we see ascend, exceptions to the general rule?

Father. It appears so at first sight, and it was formerly received as a general opinion, that smoke, steam, &c. possessed no weight: the discovery of the air-pump has shown the fallacy of this notion, for in an exhausted receiver, that is, in a glass jar from which the air is taken away by means of the air-pump, smoke and steam descend by their own weight as completely as a piece of lead. When we come to converse on the subject of pneumatics and hydrostatics, you will understand that the reason why smoke and other bodies ascend, is simply because they are lighter than the atmosphere which surrounds them, and the moment they reach that part of it which has the same gravity with themselves they cease to rise.

Charles. Is it then by this power that *all terrestrial* bodies remain firm on the *earth?*

Father. By gravity, bodies on all parts the earth (which you know is of a globular m) are kept on its surface, because they , wherever situated, tend to the centre; l, since all have a tendency to the centre, inhabitants of New Zealand, although rly opposite to our feet, stand as firm as do in Great Britain.

Charles. This is difficult to comprehend; ertheless, if bodies on all parts of the face of the earth have a tendency to the tre, there seems no reason why bodies uld not stand firm on one part as well another. Does this power of gravity act e on all bodies?

Father. It does, without any regard to ir figure, or size; for attraction or gravity s upon bodies in proportion to the quantity matter which they contain, that is, four es a greater force of gravity is exerted on a weight of four pounds, than upon e of a single pound. The consequence this principle is, that all bodies at equal tances from the earth fall with equal locity.

Emma. What do you mean, papa, by *velocity?*

Father. I will explain it by an example or two; if you and Charles set out together, and *you* walk a mile in half an hour, but *he* walk and run two miles in the same time, how much swifter will he go than you?

Emma. Twice as swift.

Father. He does, because, *in the same time*, he passes over twice as much space; therefore we say his velocity is twice as great as yours. Suppose a ball, fired from a cannon, pass through 800 feet in a second of time; and in the same time your brother's arrow pass through 100 feet only, how much swifter does the cannon ball fly than the arrow?

Emma. Eight times swifter.

Father. Then it has eight times the velocity of the arrow; and hence you understand that swiftness and velocity are synonymous terms; and that the velocity of a body is measured by the space it passes

over in a given time, as a second, a minute, an hour, &c.

Emma. If I let a piece of metal, as a penny piece, and a feather fall from my hand at the same time, the penny will reach the ground much sooner than the feather. Now how do you account for this if all bodies are equally affected by gravitation, and descend with equal velocities, when at the same distance from the earth?

Father. Though the penny and feather will not, in the open air, fall with equal velocity, yet if the air be taken away, which is easily done, by a little apparatus connected with the air-pump, they will descend in the same time. Therefore the true reason why light and heavy bodies do not fall with equal velocities, is, that the *former*, in proportion to its weight, meets with a much greater resistance from the air than the *latter*.

Charles. It is then, I imagine, from the same cause that if I drop the penny and a piece of light wood into a vessel of water, the penny shall reach the bottom, but the

wood, after descending a small way, rises to the surface.

Father. In this case the resisting medium is water instead of air, and the copper being about nine times heavier than its bulk of water, falls to the bottom without apparent resistance. But the wood, being much lighter than water, cannot sink in it, therefore, though by its *momentum*,* it sinks a small distance, yet as soon as that is overcome by the resisting medium, it rises to the surface, being the lighter substance.

* The explanation of this term will be found in the next Conversation.

CONVERSATION VI.

Of the Attraction of Gravitation.

[E]MMA. The term *momentum* which [you m]ade use of yesterday, is another word [which] I do not understand.

[Fat]her. If you have understood what I [have] said respecting the velocity of moving [bodie]s, you will easily comprehend what is [meant] by the word momentum.

[Th]e *momentum*, or moving force of a [body] is its weight multiplied into its veloci[ty. Y]ou may, for instance, place this pound [weigh]t upon a china plate without any dan[ger o]f breaking, but if you let it fall from [the h]eight of only a few inches it will dash [the c]hina to pieces. In the first case, the [plate] has only the pound weight to sustain, in [the ot]her, the weight must be multiplied in-

to the velocity, or, to speak in a popular manner, into the distance of the height from which it fell.

If a ball *a* (Plate 1. Fig. 6.) lean against the obstacle *b*, it will not be able to overturn it, but if it be taken up to *c* and suffered to roll down the inclined plane AB against *b* it will certainly overthrow it;—in the former case, *b* would only have to resist the weight of the ball *a*, in the latter it has to resist the weight multiplied into its motion, or velocity.

Charles. Then the momentum of a small body, whose velocity is very great, may be equal to that of a very large body with a slow velocity.

Father. It may, and hence you see the reason why immense battering rams, used by the ancients, in the art of war, have given place to cannon balls of but a few pounds weight.

Charles. I do, for what is wanting in weight, is made up by velocity.

Father. Can you tell me what velocity a cannon ball of 28 pounds must have to ef-

fect the same purposes, as would be produced by a battering ram of 15,000 pounds weight, and which, by manual strength, could be moved at the rate of only two feet in a second of time?

Charles. I think I can;—the *momentum* of the battering ram must be estimated by its weight, multiplied into the space passed over in a second, which is 15,000 multiplied by two feet equal to 30,000; now if this momentum, which must also be that of the cannon ball, be divided by the weight of the ball, it will give the velocity required; and 30,000 divided by 28, will give for the quotient 1072 nearly, which is the number of feet which the cannon ball must pass over in a second of time, in order that the momenta of the battering ram and the ball may be equal, or in other words, that they may have the same effect in beating down an enemy's wall.

Emma. I now fully comprehend what the momentum of a body is, for if I let a common trap-ball accidentally fall from my hand, upon my foot, it occasions more pain

than the mere pressure of a weight se
times heavier.

Charles. If the attraction of gravit
be a power by which bodies in general
towards each other, why do all bodies
to the earth as a centre?

Father. I have already told you tha
the great law of gravitation, the attra
of all bodies is in proportion to the qua
of matter which they contain. Now
earth, being so immensely large in com
son of all other substances in its vici
destroys the effect of this attraction bet
smaller bodies, by bringing them all t
self.—If two balls are let fall from a
tower at a small distance apart; though
have an attraction for one another, y
will be as nothing when compared wit
attraction by which they are both imp
to the earth, and consequently the tend
which they mutually have of approa
one another will not be perceived in
fall. If, however, any two bodies
placed in free space, and out of the sp
of the earth's attraction, they would, in

case, assuredly fall toward each other, and that with increased velocity as they came nearer. If the bodies were equal, they would meet in the middle point between the two; but if they were unequal, they would then meet as much nearer the larger one, as that contained a greater quantity of matter than the other.

Charles. According to this, the earth ought to move towards falling bodies, as well as they move to it.

Father. It ought, and, in just theory, it does; but when you calculate how many million of times larger the earth is than any thing belonging to it, and if you reckon at the same time, the small distances from which bodies can fall, you will know that the point where the falling bodies and earth will meet, is removed only to an indefinitely small distance from its surface, a distance much too small to be conceived by the human imagination.

We will resume the subject of gravity to-morrow.

we can have access; for a mile or two, which is much higher than, in general, we have opportunities of making experiments, is nothing in comparison of 4000 miles, the distance of the centre from the surface of the earth. But could we ascend 4000 miles above the earth, and of course be double the distance that we now are from the centre, we should there find that the attractive force would be but one fourth of what it is here; or in other words, that a body, which, at the surface of the earth, weighs one pound, and, by the force of gravity, falls through sixteen feet in a second of time, would at 4000 miles above the earth weigh but a quarter of a pound, and fall through only four feet in a second.*

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* Ex. Suppose it were required to find the weight of a leaden ball, at the top of a mountain three miles high, which, on the surface of the earth weighs 20lb.

If the semi-diameter of the earth be taken at 4000; then add to this the height of the mountain, and say as the square of 4003 is to the square of 4000, so is 20lb. to a fourth proportional; or as 16024009 : 16000000 : :

Emma. How is that known, papa, for nobody ever was there?

Father. You are right, my dear, for Garnerin, who last summer astonished all the people of the metropolis and its neighbourhood, by his flight in a balloon, ascended but a little way in comparison of the distance that we are speaking of. However, I will try to explain in what manner philosophers have come by their knowledge on this subject.

The moon is a heavy body connected with the earth by this bond of attraction, and by the most accurate observations, it is known to be obedient to the same laws as other heavy bodies are: its distance is also clearly ascertained, being about 240,000 miles, or equal to about sixty semidiameters of the earth and of course the earth's attraction upon the moon ought to diminish in the proportion of the square of this distance, that is,

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20 : 19.97 or something more than 19lb. 15½oz. which is the weight of the leaden ball at the top of the mountain.

it ought to be 60 times 60, or 3600 times less at the moon than it is at the surface of the earth. This is found to be the case.

Again, the earth is not a perfect sphere, but a spheroid, that is, of the shape of an orange, rather flat at the two ends called the poles, and the distance from the centre to the poles is about eighteen or nineteen miles less than its distance from the centre to the equator, consequently, bodies ought to be something heavier at, and near the poles, than they are at the equator, which is also found to be the case. Hence it is inferred that the attraction of gravitation varies at all distances from the centre of the earth, in proportion as the squares of those distances increase.*

Charles. It seems very surprising that philosophers who have discovered so many things, have not been able to find out the cause of gravity. Had Sir Isaac Newton been asked why a marble, dropped from the

* See Vol. II. Conver. VI.

hand, falls to the ground, could he not have assigned a reason?

Father. That great man, probably the greatest man that ever adorned this world, was as modest as he was great, and he would have told you he knew not the cause.

The excellent and learned Dr. Price, in a work which he published twenty-five years ago, asks, "who does not remember a time when he would have wondered at the question, *why does water run down hill?* What ignorant man is there who is not persuaded that he understands this perfectly? But every *improved* man knows it to be a question he cannot answer." For the descent of water, like that of other heavy bodies, depends upon the attraction of gravitation, the cause of which is still involved in darkness.

Emma. You just now said that heavy bodies by the force of gravity fall sixteen feet in a second of time, is that always the case?

Father. Yes, all bodies near the surface of the earth fall at that rate in the first

second of time, but as the attraction
vitation is continually acting, so the v
of falling bodies is an increasing, or
usually called, an *accelerating* veloci
is found by very accurate experimen
a body, descending from a consi
height by the force of gravity, falls
in the first second of time; 3 times
in the next; 5 times 16 feet in the th
times 16 feet in the fourth second of
and so on, continually increasing ac
to the odd numbers, 1, 3, 5, 7, 9, 11

CONVERSATION VIII.

Of the Attraction of Gravitation.

EMMA. And would a ball of twenty pounds weight here, weigh half an ounce less on the top of the mountain?

Father. Certainly: but you would not be able to ascertain it by means of a pair of scales and another weight, because both weights being in similar situations would lose equal portions of their gravity.

Emma. How, then, would you make the experiment?

Father. By means of one of those steel spiral-spring instruments which you have seen occasionally used, the fact might be ascertained.

Charles. I think, from what you told us yesterday, that with the assistance of your *stop-watch, I could* tell the height of any

place, by observing the number of seconds, that a marble or other heavy body would take in falling from that height.

Father. How would you perform the calculation?

Charles. I should go through the multiplications according to the number of seconds, and then add them together.

Father. Explain yourself more particularly;—supposing you were to let a marble or penny-piece fall down that deep well which we saw last summer in the brick field near Ramsgate, and that it was exactly five seconds in the descent, what would be the depth of the well?

Charles. In the first second it would fall 16 feet; in the next 3 times 16 or 48 feet; in the third 5 times 16 or 80 feet; in the fourth 7 times 16 or 112 feet; and in the fifth second 9 times 16 or 144 feet; now if I add 16, 48, 80, 112, and 144 together, the sum will be 400 feet, which, according to your rule, is the depth of the well. But *was the* well so deep?

Father. I do not think it was, but we

ıough your calculation was accurate, : was not done as nature effects her ope- ns, it was not performed in the shortest

arles. I should be pleased to know an r method; this, however, is very sim- it required nothing but multiplication ıddition.

ther. True, but suppose I had given ın example in which the number of sc- s had been fifty instead of five, the work d have taken you an hour or more to

the SQUARES *of the times increase.*" Consequently you have only to square the number of seconds, that is, you know, to multiply the number into itself; and then multiply that again by sixteen feet, the space which it describes in the first second, and you have the required answer. Now try the example of the *well.*

Charles. The square of 5, for the time, is 25, which multiplied by 16 gives 400 just as I brought it out before. Now if the seconds had been 50, the answer would be 50 times 50, which is 2500, and this multiplied by 16, gives 40,000 for the space required.

Father. I will now ask your sister a question to try how she has understood this subject. Suppose you observe by this watch that the time of the flight of your brother's arrow is exactly six seconds, to what height does it arise?

Emma. This is a different question, because here the *ascent* as well as the *fall* of the arrow is to be considered.

Father. But you will remember, that the

time of the ascent is always equal to that of the descent; for as the velocity of the descent is generated by the force of gravity, so is the velocity of the ascent destroyed by the same force.

Emma. Then the arrow was three seconds only in falling; now the square of 3 is 9, which multiplied by 16, for the number of feet described in the first second, is equal to 144 feet, the height to which it rose.

Father. Now, Charles, if I get you a bow which will carry an arrow so high as to be fourteen seconds in its flight, can you tell me the height to which it ascends?

Charles. I can now answer you without hesitation:—it will be 7 seconds in falling, the square of which is 49, and this again multiplied by 16 will give 784 feet, or rather more than 261 yards for the answer.

Father. If you will now consider the example which you did the long way, you will see that the rule which I have given you answers very completely. In the first second the body fell 16 feet, and in the next 48, these added together make 64, which is

the square of the 2 seconds multiplied by 16. The same holds true of the 3 first seconds, for in the third second it fell 80 feet, which added to the 64, give 144 equal to the square of 3 multiplied by 16. Again, in the fourth second it fell 112 feet, which added to 144, give 256 equal to the square of 4 multiplied by 16: and in the fifth second it fell 144 feet, which added to 256, give 400 equal to the square of 5 multiplied by 16. Thus you will find, the rule holds in all cases, *that the spaces described by bodies falling freely from a state of rest, increase as the* SQUARES *of the times increase.*

Charles. I think I shall not forget the rule. I will also show my cousin Henry how he may know the height to which his bow will carry.

Father. The surest way of keeping what knowledge we have obtained, is by communicating it to our friends.

Charles. It is a very pleasant circumstance indeed, that the giving away is the best method of keeping, for I am sure, the

being able to oblige one's friends is a most delightful thing.

Father. I have but a word or two more on the subject:—since the *whole spaces* described increase as the squares of the times increase, so also the *velocities* of falling bodies increase in the same proportion; for you know that the velocity must be measured by the space passed through. Thus if a person travels six miles an hour, and another person travels twelve miles in the same time, the latter will go with double the velocity of the former: consequently the *velocities* of falling bodies increase as the squares of the times increase.

If now you compare the spaces described by falling bodies in the *several moments of time taken separately*, and in their order from the beginning of the fall, then they, and consequently their velocities also, are to one another as the odd numbers, 1, 3, 5, 7, 9, 11, 13, &c. taken in their natural order, as you will observe by reflecting on the foregoing examples.

With this we conclude our present *conversation.*

[illegible]ATION IX.

[illegible]

[illegible] We are now going to treat [illegible] which is that [illegible] whole weight [illegible] and upon which [illegible] it will rest; [illegible] will endeavour [illegible] which it

[illegible] whatever [illegible]

[illegible] you conceive [illegible] gravity of [illegible] the earth, that [illegible] direction, [illegible] body, not supported, [illegible] to fall. If the line of direction fall [illegible] the base of any body, it will stand

f it does not fall within the base, the will fall.

I place the piece of wood A (Plate I. 7.) on the edge of a table, and from a at its centre of gravity be hung a little ht *b*, the line of direction *ab* falls within base, and therefore, though the wood , yet it stands secure. But if upon A, her piece of wood B be placed, it is evi- that the centre of gravity of the whole be now raised to *c*, at which point if a ht be hung, it will be found that the line rection falls out of the base, and there- the body must fall.

mma. I think I now see the reason of advice which you gave me, when we going across the Thames in a boat.

ther. I told you that if ever you were taken by a storm, or by a squall of wind e you were on the water, never to let your so get the better of you, as to make rise from your seat, because by so do- ou would elevate the centre of gravity, thereby, as is evident by the last expe- nt, increase the danger: whereas, if all

the persons in the vessel were, at the moment of danger, instantly to slip from their places on to the bottom, the risque would be exceedingly diminished, by bringing the centre of gravity much lower within the vessel. The same principle is applicable to those who may be in danger of being overturned in any carriage whatever.

Emma. Surely then, papa, those stages which load their tops with a dozen or more people, cannot be safe for the passengers.

Father. They are very unsafe, but they would be more so, were not the roads about the metropolis remarkably even and good: and, in general, it is only within twenty or thirty miles of London, or other great towns, that the tops of carriages are loaded to excess.

Charles. I understand then, that the nearer the centre of gravity is to the base of a body, the firmer it will stand.

Father. Certainly; and hence you learn the reason why conical bodies stand so sure on their bases, for the tops being small i[illegible]ison of the lower parts, the centre

of gravity is thrown very low: and if the cone be upright or perpendicular, the line of direction falls in the middle of the base, which is another fundamental property of steadiness in bodies. For the broader the base, and the nearer the line of direction is to the middle of it, the more firmly does a body stand: but if the line of direction fall near the edge, the body is easily overthrown.

Charles. Is that the reason why a ball is so easily rolled along a horizontal plane?

Father. It is; for in all spherical bodies, the base is but a point, consequently almost the smallest force is sufficient to remove the line of direction out of it. Hence it is evident, that heavy bodies situated on an inclined plane will, while the line of direction falls within the base, slide down upon the plane: but they will roll when that line falls without the base. The body A (Plate I. Fig. 8.) will slide down the plane DE, but the bodies B and C will roll down it.

Emma. I have seen buildings lean very much out of a straight line, why do they not fall?

Father. It does not follow because a building leans, that the centre of gravity does not fall within the base. There is a high tower at Pisa, a town in Italy, which leans fifteen feet out of the perpendicular; strangers tremble to pass by it, still it is found by experiment that the line of direction falls within the base, and therefore it will stand while its materials hold together.

A wall at Bridgenorth in Shropshire, which I have seen, stands in a similar situation, for so long as a line *cb* (Plate II. Fig. 9.) let fall from the centre of gravity *c* of the building AB, passes within the base CB, it will remain firm, unless the materials with which it is built go to decay.

Charles. It must be of great use in many cases to know the method of finding the centre of gravity in different kinds of bodies.

Father. There are many easy rules for this with respect to all manageable bodies: I will mention one, which depends on the property which the centre of gravity has, of always endeavouring to descend to the lowest point.

If a body A (Plate II. Fig. 10.) be freely suspended on a pin *a*, and a plumb line *a* B be hung by the same pin, it will pass through the centre of gravity, for that centre is not in the lowest point, till it fall in the same line as the plumb line. Mark the line *a* B; then hang the body up by any other point, as D, with the plumb line DE, which will also pass through the centre of gravity for the same reason as before: and therefore as the centre of gravity is somewhere in *a* B, and also in some point of DE, it must be in the point C where those lines cross.

CONVERSATION X.

Of the Centre of Gravity.

CHARLES. How do those people who have to load carts and waggons with light goods, as hay, wool, &c. know where to find the centre of gravity?

Father. Perhaps the generality of them never heard of such a principle; and it seems surprising that they should nevertheless make up their loads with such accuracy as to keep the line of direction in or near the middle of the base.

Emma. I have sometimes trembled to pass by the hop-waggons which we have met on the Kent road.

Father. And without any impeachment of your courage, for they are loaded to such an enormous height, that they totter ' inch of the road. It would indeed

be impossible for one of these to pass with tolerable security along a road much inclined; the centre of gravity being removed so high above the body of the carriage, a small declination on one side or other would throw the line of direction out of the base.

Emma. When brother James falls about, is it because he cannot keep the centre of gravity between his feet?

Father. That is the precise reason why any person, whether old or young, falls. And hence you learn that a man stands much firmer with his feet a little apart than if they were quite close, for by separating them he increases the base. Hence also the difficulty of sustaining a tall body, as a walking cane, upon a narrow foundation.

Emma. How do rope and wire dancers, whom I have seen at the Circus, manage to balance themselves?

Father. They generally hold a long pole, with weights at each end, across the rope on which they dance, keeping their eyes fixed on some object *parallel* to the rope, by *which means they know* when their centre

of gravity declines to one side of the rope or the other, and thus by the help of the pole, they are enabled to keep the centre of gravity over the base, narrow as it is. It is not however rope-dancers only that pay attention to this principle, but the most common actions of the people in general are regulated by it.

Charles. In what respects?

Father. We bend forward, when we go up stairs, or rise from our chair, for when we are sitting, our centre of gravity is on the seat, and the line of direction falls behind our base; we therefore lean forwards to bring the line of direction towards our feet. For the same reason a man carrying a burden on his back leans forward: and backward if he carries it on his breast. If the load be placed on one shoulder he leans to the other. If we slip or stumble with one foot, we naturally extend the opposite arm, making the same use of it as the rope-dancer does of his pole.

This property of the centre of gravity always endeavouring to descend, will account

for appearances, which are sometimes exhibited to excite the surprise of spectators.

Emma. What are those, papa?

Father. One is, that of a double cone, appearing to roll up two inclined planes, forming an angle with each other, for as it rolls it sinks between them, and by that means the centre of gravity is actually descending.

Let a body EF (Plate II. Fig. 13.) consisting of two equal cones united at their bases, be placed upon the edges of two straight smooth rulers, AB and CD, which at one end meet in an angle at A, and rest on a horizontal plane; and at the other are raised a little above the plane; the body will roll towards the elevated end of the rulers, and appear to ascend; the parts of the cone that rest on the rulers growing smaller as they go over a large opening, and thus letting it down, the centre of gravity descends. But you must remember that the height of the planes must be less than the *radius of the base* of the cone.

Charles. Is it upon this principle that a cylinder is made to roll up hill?

Father. Yes, it is; but this can be effected only to a small distance. If a cylinder of pasteboard, or very light wood A B, (Plate II. Fig. 11.) having its centre of gravity at *c*, be placed on the inclined plane CD, it will roll down the inclined plane, because a line of direction from that centre lies out of the base. If I now fill the little hole *o* above with a plug of lead, it will roll up the inclined plane, till the lead gets near the base, where it will lie still: because the centre of gravity by means of the lead is removed from *c* towards the plug, and therefore is descending, though the cylinder is ascending.

Before I put an end to this subject, I will shew you another experiment, which without understanding the principle of the centre of gravity cannot be explained. Upon this stick A, (Plate II. Fig. 12.) which, of itself, would fall, because its centre of gravity hangs over the table EF, I suspend a bucket B, fixing another stick *a*, one end

Charles. There is no difficulty of conceiving that a body, as this inkstand, in a state of rest must always remain so, if no external force be impressed upon it to give it motion. But I know of no example which will lead me to suppose, that a body once put into motion would of itself continue so.

Father. You will, I think, presently admit the latter part of the assertion as well as the former, although it cannot be established by experiment.

Emma. I shall be glad to hear how this is.

Father. You will not deny that the ball which you strike from the trap, has no more power either to destroy its motion, or cause any change in its velocity, than it has to change its shape.

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name; to him, however, their reasonings appear inconclusive. At any rate, in a work intended for very young minds, he thinks it a duty to avoid metaphysical distinctions: preferring, at all times, rather to guide them by matters of fact, than to load their tender memories with curious and subtile theories.

Charles. Certainly; nevertheless, in a few seconds after I have struck the ball with all my force, it falls to the ground, and then stops.

Father. Do you find no difference in the time that is taken up before it comes to rest, even supposing your blow the same?

Charles. Yes, if I am playing on the grass it rolls to a less distance, than when I play on the smooth gravel.

Father. You find a like difference when you are playing at marbles, if you play in the gravel court, or on the even pavement in the arcade.

Charles. The marbles run so easily on the smooth stones in the arcade, that we can scarcely shoot with a force small enough.

Emma. And I remember Charles and my cousin were, last winter, trying how far they could shoot their marbles along the ice in the canal; and they went a prodigious distance, in comparison of that which they would have gone on the gravel, or even on the pavement in the arcade.

Father. Now these instances properly applied will convince you, that a body once put into motion, would go on for ever, if it were not compelled by some external force to change its state.

Charles. I perceive what you are going to say :—it is the rubbing or friction of the marbles against the ground which does the business. For on the pavement there are fewer obstacles than on the gravel, and fewer on the ice than on the pavement; and hence you would lead us to conclude, that if all obstacles were removed, they might proceed on for ever. But what are we to say of the ball, what stops that?

Father. Besides friction, there is another and still more important circumstance to be taken into consideration, which affects the ball, marbles, and every body in motion.

Charles. I understand you, that is the attraction of gravitation.

Father. It is: for from what we said when we *conversed* on that subject, it appeared that gravity has a tendency to bring

every body in motion to the earth; consequently, in a few seconds, your ball must come to the ground by that cause alone; but besides the attraction of gravitation, there is a resistance which the air, through which the ball moves, makes to its passage.

Emma. That cannot be much I think.

Father. Perhaps, with regard to the ball struck from your brother's trap, it is of no great consideration, because the velocity is but small; but in all great velocities, as that of a ball from a musket or cannon, there will be a material difference between the theory and practice, if it be neglected in the calculation. Move your mamma's riding-whip through the air slowly, and you observe nothing to remind you that there is this resisting medium; but if you swing it with considerable swiftness, the noise which it occasions will inform you of the resistance it meets with from something which is the atmosphere.

Charles. If I now understand you, the force which compels a body in motion to stop, is of three kinds; (1.) the attraction

avitation;—(2.) the resistance of the -and (3.) the resistance it meets with friction.

ther. You are quite right.

arles. I have no difficulty of conceiv- hat a body in motion, will not come tate of rest, till it is brought to it by cternal force, acting upon it in some or other. I have seen a gentleman, skaiting on very slippery ice, go a way without any exertion to himself, here the ice was rough, he could not lf the distance without making fresh s.

ther. I will mention another instance on this law of motion. Put a basin ter into your little sister's waggon, and the water is perfectly still, move the on, and the water, resisting the motion e vessel, will at first rise up in the tion contrary to that in which the l moves. If, when the motion of the l is communicated to the water, you enly stop the waggon, the water, in en-

deavouring to continue the state of motion, rises up on the opposite side.

In like manner, if while you are sitting quietly on your horse, the animal starts forward, you will be in danger of falling off backward; but if while you are galloping along, the animal stops on a sudden, you will be liable to be thrown forward.

Charles. This I know by experience, but I was not aware of the reason of it till to-day.

Father. One of the first, and not least important uses of the principles of natural philosophy is, that they may be applied to, and will explain many of the common concerns of life.

We now come to the *second* law of motion, which is;—"*that the change of motion is proportional to the force impressed, and in the direction of that force.*"

Charles. There is no difficulty in this, for if while my cricket-ball is rolling along after Henry has struck it, I strike it again, it *goes on* with increased velocity, and that in *proportion to* the strength which I exert on

occasion; whereas, if while it is rolling, strike it back again, or give it a side blow, change the direction of its course.

Father. In the same way, gravity, and the resistance of the atmosphere, change the direction of a cannon-ball from its course in a straight line, and bring it to the ground; and the ball goes to a farther or less distance in proportion to the quantity of powder used.

The *third* law of motion is;—"*that to every action of one body upon another, there is an equal and contrary re-action.*" If I strike this table, I communicate to it (which you perceive by the shaking of the glasses) the motion of my hand; and the table re-acts against my hand just as much as my hand acts against the table.

If you press with your finger one scale of a balance, to keep it in equilibrio with a pound weight in the other scale, you will perceive, that the scale pressed by the finger, acts against it with a force equal to the pound, with which the other scale endeavours to descend.

A horse drawing a heavy load, is as much drawn back by the load as he draws it forward.

Emma. I do not comprehend how the cart draws the horse.

Father. But the progress of the horse is impeded by the load, which is the same thing: for the force which the horse exerts would carry him to a greater distance in the same time, were he freed from the encumbrance of the load, and therefore, as much as his progress falls short of that distance, so much is he, in effect, drawn back by the re-action of the loaded cart.

Again, if you and your brother were in a boat, and if, by means of a rope, you were to attempt to draw another to you, the boat in which you were would be as much pulled toward the empty boat as that would be moved to you; and if the weight of the two boats were equal, they would meet in a point half way between the two.

If you strike a glass bottle with an iron *hammer*, the blow will be received by the *hammer* and the glass; and it is immateri-

al whether the hammer be moved against the bottle at rest, or the bottle be moved against the hammer at rest, yet the bottle will be broken, though the hammer be not injured, because the same blow, which is sufficient to break glass, is not sufficient to break or injure a mass of iron.

From this law of motion you may learn in what manner a bird by the stroke of its wings, is able to support the weight of its body.

Charles. Pray explain this, papa.

Father. If the force with which it strikes the air below it, is *equal* to the weight of its body, then the re-action of the air upwards is likewise equal to it; and the bird being acted upon by two *equal* forces in contrary directions, will rest between them. If the force of the stroke is *greater* than its weight, the bird will rise with the *difference* of these two forces: and if the stroke be *less* than its weight, then it will sink with the *difference*.

CONVERSATION XII.

On the Laws of Motion.

CHARLES. Are those laws of n
which you explained yesterday of gre
portance in natural philosophy ?

Father. Yes, they are, and shou
carefully committed to memory.
were assumed by Sir Isaac Newton,
fundamental principles of mechanics
you will find them at the head of all
written on these subjects. From th
so, we are naturally led to some
branches of science, which, though w
not but slightly mention, should n
wholly neglected. They are, in fac
corollaries to the laws of motion.

Emma. What is a corollary, papa

e in all bodies, he called their *vis inertiæ.*

Charles. A few mornings ago, you showed us that the attraction of the earth upon the moon* is 3600 times less than it is upon heavy bodies near the earth's surface. Now as this attraction is measured by the space fallen through in a given time, I have endeavoured to calculate the space which the moon would fall through in a minute, were the projectile force to cease.

Father. Well, and how have you brought it out?

Charles. A body falls here 16 feet in the first second, consequently in a minute, or 60 seconds, it would fall 60 times 60 feet, multiplied by 16, that is 3600 feet, which is to be multiplied by 16; and as the moon would fall through 3600 times less space in a given time than a body here, it would fall only 16 feet in the first *minute.*

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* See Conversation IV.

Father. Your calculation is accurate. I will recall to your mind the *second* law, by which it appears, *that every motion or change of motion produced in a body, must be proportional to, and in the direction of, the force impressed.* Therefore, if a moving body receives an impulse in the direction of its motion, its velocity will be increased;—if, in the contrary direction, its velocity will be diminished;—but if the force be impressed in a direction oblique to that in which it moves, then its direction will be between that of its former motion, and that of the new force impressed.

Charles. This I know from the observations I have made with my cricket-ball.

Father. By this second law of motion, you will easily understand, that if a body at rest, receives two impulses, at the same time, from forces whose directions do not coincide, it will, by their joint action, be made to move in a line that lies between the direction of the forces impressed.

Emma. Have you any machine to prove this satisfactorily to the senses?

Father. There are many such invented by different persons, descriptions of which, you will hereafter find in various books on these subjects. But it is easily understood by a figure. If on the ball A, (Plate II. Fig. 14.) a force be impressed, sufficient to make it move with an uniform velocity to the point B, in a second of time; and if another force be also impressed on the ball, which alone would make it move to the point C, in the same time; the ball, by means of the two forces, will describe the line A D, which is a diagonal of the figure, whose sides are A C and A B.

Charles. How then is motion produced in the *direction of the force:* according to the second law, it ought to be in one case, in the direction A C, and in the other, in that of A B, whereas, it is in that of A D?

Father. Examine the figure a little attentively, carrying this in your mind, that for a body to move in the *same direction,* it is *not* necessary that it should move in the *same straight line;* but that it is *sufficient to move either* in that line, or in any *one parallel to it.*

Charles. I perceive then that the ball when arrived at D, has moved in the direction A C, because B D is parallel to A C; and also in the direction A B, because C D is parallel to it.

Father. And in no other possible situation but at the point D, could this experiment be conformable to the second law of motion.

CONVERSATION XIII.

Of the Laws of Motion.

ATHER. If you reflect a little upon
t we said yesterday on the second law
notion, you will readily deduce the
wing corollaries. (Plate II. Fig. 14.)

That if the forces be equal, and
it right angles to one another, the line
ribed by the ball will be the diagonal
square. But in all other cases, it will
he diagonal of a parallelogram of some
d.

. By varying the angle, and the for-
you vary the form of your parallelo-
m.

harles. Yes, papa; and I see another
sequence, viz. that the motions of

two forces acting conjointly in this w
are not so great as when they act se
rately.

Father. That is true, and you are
to the conclusion, I suppose, from the
collection that in every triangle any t
sides taken together are greater than
remaining side; and therefore you inf
and justly too, that the motions which
ball A must have received, had the for
been applied separately, would have b
equal to A C and A B, or, which is
same thing, to A C, and C D, the two si
of the triangle A D C, but by their jo
action the motion is only equal to A D,
remaining side of the triangle.

Hence then you will remember, that
the *composition*, or adding together
forces (as this is called) motion is alwa
lost: and in the *resolution* of any one fo
as A D, into two others A C and A B, m
tion is gained.

Charles. Well, papa, but how is
that the heavenly bodies, the moon for i
stance, which is impelled by two forc

performs her motion in a circular curve round the earth, and not in a diagonal between the direction of the projectile force and that of the attraction of gravity to the earth.

Father. Because in the case just mentioned, there was but the action of a single impulse in each direction, whereas the action of gravity on the moon is continual, and causes an accelerated motion, and hence the line is a curve.

Charles. Supposing then, that A represent the moon, and A C the sixteen feet through which it would fall in a second by the attraction of gravity towards the earth, and A B represent the projectile force acting upon it for the same time. If A B and A C acted as single impulses, the moon would in that case describe the diagonal A D: but since these forces are constantly acting, and that of gravity is an accelerating force also, therefore instead of the straight line A D, the moon will be drawn into the curve line A *a* D. Do I understand the matter right?

Father. You do; and hence
comprehend how by good instru
calculation, the attraction of the
the moon was discovered.

The *third* law of motion, vi
tion and re-action are equal and
directions, may be illustrated by
communicated by the percussion
and *non-elastic* bodies.

Emma. What are these, papa

Father. *Elastic* bodies, are t
have a certain spring, by which
upon being pressed inwards, by
return to their former state; th
is evident in a ball of wool
or in spunge compressed. *Non*
dies are those which, when one
other, do not rebound, but mo
after the stroke.

Let two *equal* ivory balls *a* an
pended by threads; if *a* (Plate 1
be drawn a little out of the per
and let fall upon *b*, it will lose
by communicating it to *b*, whi
driven to a distance *c*, equal to t

hich *a* fell; and hence it appears that the e-action of *b*, was equal to the action of upon it.

Emma. But do the parts of the ivory alls yield by the stroke, or, as you call it, y the percussion?

Father. They do; for if I lay a little aint on *a*, and let it *touch* *b*, it will make ut a very small speck upon it: but if it *ll* upon *b*, the speck will be much larger; hich proves that the balls are elastic, id that a little hollow, or dint, was made each by collision. If now two equal ft balls of clay, or glazier's putty, which e non-elastic, meet each other with equal elocities, they would stop and stick toge-er at the place of their meeting, as their utual actions destroy each other.

Charles. I have sometimes shot my hite alley against another marble so umply, that the marble has gone off as viftly as the alley approached it, and at remained in the place of the marble. re marbles therefore, as well as ivory, astic?

Father. They are.—If three elas
a, b, c, (Plate III. Fig. 16.) be hu
adjoining centres, and c be drawn
out of the perpendicular, and let f
b, then will c and b become stationa
a will be driven to o, the distance
which c fell upon b.

If you hang any number of balls
eight, &c. so as to touch each other
you draw the outside one away to
distance, and then let it fall upon th
the ball on the opposite side will b
off, while the rest remain station
equally is the action and re-action
stationary balls divided among th
the same manner, if two are dra
and suffered to fall on the rest, th
site two will fly off, and the others
stationary.

There is one other circumstance
ing upon the action, and re-action o
and also upon the *vis inertiæ* of
worth noticing: by some authors
find it largely treated upon.

If I strike a blacksmith's anvil

ıer, action and re-action being equal, ıvil strikes the hammer as forcibly as aınmer strikes the anvil.

the anvil be large enough, I might lay my breast, and suffer you to strike it ı sledge hammer with all your strength, ut pain or risque, for the *vis inertiæ* e anvil resists the force of the blow.

f the anvil were but a pound or two ight, your blow would probably kill

CONVERSATION XIV.

On the Mechanical Powers.

CHARLES. Will you now, papa, explain the mechanical powers?

Father. I will, and I hope you have not forgotten what the *momentum* of a body is.

Charles. No; it is the force of a moving body, which force is to be estimated by the weight, multiplied into its velocity.

Father. Then a small body may have an equal momentum with one much larger?

Charles. Yes, provided the smaller body moves as much swifter than the larger one, as the weight of the latter is greater than that of the former.

Father. Yes, the greater the distance at which these seats were placed from the centre of motion, the greater was the space which the little boys and girls travelled for their half-penny.

Emma. Then those in the second row had a shorter ride for their money, than those at the end of the poles.

Father. Yes, shorter as to space, but the same as to time. In the same way, when you and Charles go round the gravel-walk for half an hour's exercise, if he run, while you walk, he will, perhaps, have gone six or eight times round, in the same time that you have been but three or four times; now, as to time, your exercise has been equal, but he may have passed over double the space in the same time.

Charles. How does this apply to the explanation of the mechanical powers?

Father. You will find the application very easy:——without clear ideas of what is meant by *time* and *space*, it were in vain to expect you to comprehend the principles of *mechanics*.

There are six mechanical powers. T
lever; the wheel and axle; the pully;
inclined plane; the wedge; and the scr

Emma. Why are they called mechan
powers?

Father. Because, by their means we
enabled *mechanically* to raise weights, m
heavy bodies, and overcome resistan
which, without their assistance, could
be done.

Charles. But is there no limit to the
sistance gained by these powers? for I
member reading of Archimedes, who s
that with a place for his fulcrum he wo
move the earth itself.

Father. Human power, with all the
sistance which art can give, is very soo
mited, and upon this principle, *that w*
we gain in power, we lose in time. Tha
if by your own unassisted strength, you
able to raise fifty pounds to a certain
tance in one minute, and if by the hel
machinery, you wish to raise 500 pound
the same height, you will require ten
nutes to perform it in; thus you incr

your power ten-fold, but it is at the expense of time. Or, in other words, you are enabled to do that with one effort in ten minutes, which you could have done in ten separate efforts in the same time.

Emma. The importance of mechanics, then, is not so very considerable as one, at first sight, would imagine; since there is no real gain of force acquired by the mechanical powers.

Father. Though there be not any actual increase of force gained by these powers; yet, the advantages which men derive from them are inestimable. If there are several small weights, manageable by human strength, to be raised to a certain height, it may be full as convenient to elevate them one by one, as to take the advantage of the mechanical powers in raising them all at once. Because, as we have shown, the same time will be necessary in both cases. But suppose you have a large block of stone of a ton weight to carry away, or a weight still *greater, what is to be* done?

Emma. I did not think of that.

Father. Bodies of this kind cannot be separated into parts proportionable to the human strength without immense labour, nor, perhaps, without rendering them unfit for those purposes to which they are to be applied. Hence then you perceive the great importance of the mechanical powers, by the use of which a man is able with ease to manage a weight many times greater than himself.

Charles. I have, indeed, seen a few men, by means of pulleys, and seemingly with no very great exertion, raise an enormous oak into a timber-carriage, in order to convey it to the dock-yard.

Father. A very excellent instance; for if the tree had been cut into such pieces as could have been managed by the natural strength of these men, it would not have been worth carrying to Deptford or Chatham for the purpose of ship-building.

Emma. I acknowledge my error;—what is a fulcrum, papa?

Father. It is a *fixed point*, or drop, round which the other parts of a machine move.

Charles. The pivot, upon which the hands of your watch move, is a fulcrum then.

Father. It is, and you remember we called it also the centre of motion: the rivet of these scissars is also a fulcrum.

Emma. Is that a fixed point or prop?

Father. Certainly it is a fixed point, as it regards the two parts of the scissars; for that always remains in the same position, while the other parts move about it. Take the poker and stir the fire; now that part of the bar on which the poker rests is a fulcrum, for the poker moves upon it as a centre.

CONVERSATION XV.

Of the Lever.

FATHER. We will now consider the *Lever*, which is generally called the first mechanical power.

The *Lever*, is any inflexible bar of wood, iron, &c. which serves to raise weights, while it is supported at a point by a prop or fulcrum, on which, as the centre of motion, all the other parts turn. A B (Plate III. Fig. 17.) will represent a lever, and the point C the fulcrum or centre of motion. Now, it is evident, if the lever turn on its centre of motion C, so that A comes into the position *a*; B at the same time must come *into* the position *b*. If both the arms of the le- *ver be equal*, that is, if A C is equal to B C,

there is no advantage gained by it, for they pass over equal spaces in the same time; and according to the fundamental principle already laid down (p. 104) "as advantage or power is gained, time must be lost:" therefore no time being lost by a lever of this kind, there can be no power gained.

Charles. Why then is it called a mechanical power?

Father. Strictly speaking perhaps it ought not to be numbered as one. But it is usually reckoned among them, having the fulcrum between the weight and the power, which is the distinguishing property of levers of the first kind. And when the fulcrum is exactly the middle point between the weight and power, it is the common balance: to which, if scales be suspended at A B, it is fitted for weighing all sorts of commodities.

Emma. You say it is a lever of the *first* kind, are there several sorts of levers?

Father. There are three sorts; some persons *reckon four*, the fourth however, is *but a bended one* of the first kind. A lever

of the *first* kind (Plate III. Fig. 18, 19.) has the fulcrum between the weight and power.

The *second* kind of lever (Plate III. Fig. 20.) has the fulcrum at one end, the power at the other, and the weight between them.

In the *third* kind (Plate III. Fig. 21.) the power is between the fulcrum and the weight.

Of Levers' powers the different sorts are three,
The *first* in steel-yards and in the scales you see;
The best a *second* is the miller's lift,
Where *power* and *fulcrum* to each end you shift;
And in the *third*, the worst of all, my friend,
You find the *weight* and *fulcrum* at each end.

Let us take the lever of the first kind, (Fig. 18.) which if it be moved into the position a b, by turning on its fulcrum C, it is evident that while A has travelled over the short space A a, B has travelled over the greater space B b, which spaces are to one another, exactly in proportion to the length of the arms A C and B C. If now you apply

our hand first to the point A, and afterwards to B, in order to move the lever into the position *a b*, using the same velocity in both cases, you will find that the time spent in moving the lever when the hand is at B, will be as much greater, as that spent when the hand is at A, as the arm B C is longer than the arm A C, but then the exertion required will, in the same proportion, be less at B than at A.

Charles. The arm B C appears to be four times the length of A C.

Father. Then it is a lever which gains power in the proportion of four to one. That is, a single pound weight applied to the end of the arm B C, as at P, will balance four pounds suspended at A, as W.

Charles. I have seen workman move large pieces of timber to very small distances, by means of a long bar of wood or iron; is that a lever?

Father. It is; they force one end of the bar under the timber, and then place a block of wood, stone, &c. beneath, and as near the same end of the lever as possible, for a

fulcrum, applying their own strengt other: and power is gained in pr as the distance from the fulcrum to where the men apply their stre greater than the distance from the to that end under the timber.

Charles. It must be very consider I have seen two or three men mov in this way, of several tons weight think.

Father. That is not difficult; for ing a lever to gain the advantage o to one, and a man by his natural str able to move but a hundred weight, find that by a lever of this sort, he c twenty hundred weight or a ton; single exertions, a strong man can p a much greater power, than that sufficient to remove a hundred weig levers are also frequently used, the ad gained by which is still more cons than twenty to one.

Charles. I think you said, the ot that the common steel-yard made u the butcher, is a lever.

Father. I did; the short arm A C (Plate XII. Fig. 19.) is, by an increase in size, made to balance the longer one B C, and from C, the centre of motion, the divisions must commence. Now if B C be divided into as many parts as it will contain, each equal to A C; a single weight, as a pound P, will serve for weiging any thing as heavy as itself, or as many times heavier as there are divisions in the arm C. If the weight P be placed at the division 1, in the arm B C, it will balance one pound in the scale at A: if it be removed to 3, 5, or 7, it will balance 3, 5, or 7 pounds in the scale; for these divisions being respectively 3, 5, or 7 times the distance from the centre of motion C, that A is, it becomes a lever, which gains advantage at those points, in the proportion of 3, 5, and 7. If now the intervals between the divisions on the longer arm be subdivided into halves, quarters, &c. any weight may be accurately ascertained to halves, quarters of pounds, &c.

CONVERSATION XVI.

Of the Lever.

EMMA. What advantage has th
yard, which you described in our l
versation, over a pair of scales?

Father. It may be much more re
moved from place to place; it req
apparatus, and only a single weigh
the purposes to which it can be ap
Sometimes the arms are not of equal
In that case the weight P must b
along the arm B C, till it exactly bal
other arm without a weight, and
point a notch must be made, marki
it a cipher O, from whence the c
must commence.

Charles. Does there require great accuracy in the manufacture of instruments of this kind?

Father. Yes, of such importance is it to the public, that there should be no error or fraud by means of false weights or false balances, that it is the business of certain public officers to examine at stated seasons the weights, measures, &c. of every shopkeeper in the land. Yet it is to be feared that after all precautions, much fraud is practised upon the unsuspecting.

Emma. I one day last summer bought, as I supposed, a pound of cherries at the door, but Charles thinking there were not a pound, we tried them in your scales and found but twelve ounces, or three quarters, instead of a pound, and yet the scale went down as if the man had given me full weight. How was that managed?

Father. It might be done many ways: by short weights;—or by the scale in which the fruit was put, being heavier than the other;—but fraud may be practised with honest weights and scales, by making the

arm of balance on which the weights hang, shorter than the other, for then a pound weight will be balanced by as much less fruit than a pound, as that arm is shorter than the other; this was probably the method by which you were cheated.

Emma. By what method could I have discovered this cheat?

Father. The scales when empty are exactly balanced, but when loaded, though still in equilibrio, the weights are unequal, and the deceit is instantly discovered by changing the weights to the contrary scales. I will give you a rule to find the true weight of any body by such a false balance, the reason of the rule you will understand hereafter, "*Find the weights of the body by both scales, multiply them together, and then find the square root of the product, which is the true weight.*"

Charles. Let me see if I understand the rule: suppose a body weigh 16 ounces in one scale, and in the other 12 ounces and a quarter, I multiply 16 by 12 and a quarter, and I get the product 196, the square roo

[o]f which is 14 : for 14 multiplied into itself [gi]ves 196 ; therefore the true weight of the [b]ody is 14 ounces.

Father. That is just what I meant.—To [th]e lever of the first kind may be referred [m]any common instruments, such as scissars, [pi]ncers, snuffers, &c. which are made by [tw]o levers, acting contrary to one another.

Emma. The rivet is the fulcrum, or cen[tr]e of motion, the hand the power used, and [w]hatever is to be cut, is the resistance to [b]e overcome.

Charles. A poker stirring the fire is also [a] lever, for the bar is the fulcrum, the hand [th]e power, and the coals the resistance to [b]e overcome.

Father, We now proceed to levers of the [se]cond kind, in which the fulcrum C (Fig. [2]0.) is at one end, the power P applied at [th]e other B, and the weight to be raised W, [so]mewhere between the fulcrum and the [po]wer.

Charles. And how is the advantage gain[ed] to be estimated in this lever?

Father. By looking at the figure you will find that power or advantage is gained in proportion as the distance B, the point at which the power P acts, is greater than the distance of the weight W from the fulcrum.

Charles. Then if the weight hang at one inch from the fulcrum, and the power acts at five inches from it, the power gained is five to one, or one pound at P will balance five at W?

Father. It will; for you perceive that the power passes over five times as great a space as the weight, or while the point A in the lever moves over one inch, the point B will move over five inches.

Emma. What things in common use are to be referred to the lever of the second kind?

Father. The most common and useful of all things; every door, for instance, which turns on hinges is a lever of this sort. The hinges may be considered as the fulcrum or centre of motion, the whole door is

eight to be moved, and the power is ed to that side on which the lock is lly fixed.

nma. Now I see the reason why there nsiderable difficulty in pushing open a y door, if the hand is applied to the next the hinges, although it may be ed with the greatest ease in the usual od.

arles. This sofa, with sister upon it, sents a lever of the second kind.

ther. Certainly, if while she is sitting it, in the middle, you raise one end, e the other remains fixed as a prop or um. To this kind of lever may be also ced nut-crackers; oars; rudders of ; those cutting knives which have one fixed in a block, such as are used for ng chaff, drugs, wood for pattens, &c.

mma. I do not see how oars and rud- are levers of this sort.

ather. The boat is the weight to be ed, the water is the fulcrum, and the rman at the handle the power. The s of ships are also levers of the second

kind, for the bottom of the vessel is fulcrum, the ship the weight, and the acting against the sail is the moving p

The knowledge of this principle m useful in many situations and circumst of life:—if two men unequal in str have a heavy burden to carry on a between them, the ability of each m consulted by placing the burden as nearer to the stronger man, as his str is greater than that of his partner.

Emma. Which would you call th in this case?

Father. The stronger man, fo weight is nearest to him, and the weaker must be considered as the p Again, two horses may be so yoke carriage that each shall draw a part p tional to his strength, by dividing the in such a manner, that the point of *tr* or drawing, may be as much nearer stronger horse than to the weaker, strength of the former exceeds that latter.

We will now describe the third k lever. In this the prop or fulcrum c

s at one end the weight W at the and the power P is applied at B some- between the prop and weight.

rles. In this case, the weight being r from the centre of motion than the , must pass through more space than it.

her. And what is the consequence t?

rles. That the power must be greater he weight and as much greater as the ce of the weight from the prop ex- the distance of the power from it, that balance a weight of three pounds at re will require the exertion of a power ng at B, equal to five pounds.

her. Since then a lever of this kind isadvantage to the moving power, it seldom used, and only in cases of ne- y; such as in that of a ladder, which fixed at one end against a wall or obstacle, is by the strength of a man's aised into a perpendicular situation. he most important application of this kind of lever, is manifest in the struc- of the limbs of animals, particularly

in those of man; to take the arm as an instance: when we lift a weight by the hand, it is effected by means of muscles coming from the shoulder blade, and terminating about one tenth as far below the elbow as the hand is: now the elbow being the centre of motion round which the lower part of the arm turns, according to the principle just laid down, the muscles must exert a force ten times as great as the weight that is raised. At first view this may appear a disadvantage, but what is lost in power is gained in velocity, and thus the human figure is better adapted to the various functions it has to perform.

CONVERSATION XVII.

Of the Wheel and Axis.

FATHER. Well, Emma, do you un-erstand the principle of the lever, which re discussed so much at large yesterday?

Emma. The lever gains advantage, in roportion to space passed through by the cting power; that is, if the weight to be aised, be at the distance of one inch from he fulcrum, and the power is applied nine nches distant from it, then it is a lever, which gains advantage as 9 to 1, because he space passed through by the *power* is nine times greater than that passed through by the weight; and, therefore, what is lost in time by passing through a greater space, is gained in power.

acting at P, must be as much greater than that of W, as A C is less than B C, and then they will be in equilibrio.

Father. The second mechanical power is the *Wheel and Axis*, which gains power in proportion, as the circumference of the wheel is greater than that of the axis; this machine may be referred to the principle of the lever. A B (Plate III. Fig. 22.) is the wheel, Q D its axis, and if the circumference of the wheel be eight times as great as that of the axis, then a single pound P, will balance a weight W, of eight pounds.

Charles. Is it by an instrument of this kind that water is drawn from those deep wells so common in many parts of the country?

Father. It is; but as in most cases of this kind only a single bucket is raised at once, there requires but little power in the operation, and therefore, instead of a large wheel as A B, an iron handle fixed at B is made use of, which, you know, by its circular motion, answers the purpose of a *wheel.*

Charles. I once raised some water by a machine of this kind, and I found, that as the bucket ascended nearer the top the difficulty increased.

Father. That must always be the case, where the wells are so deep as to cause, in the ascent, the rope to coil more than once the length of the axis, because the advantage gained is in proportion as the circumference of the wheel is greater than that of the axis; so that if the circumference of the wheel be 12 times greater than that of the axis, 1 pound applied at the former, will balance 12 hanging at the latter; but by the coiling of the rope round the axis, the *difference* between the circumference of the wheel, and that of the axis continually diminishes, consequently the advantage gained is less every time a new coil of rope is wound on the whole length of the axis; this explains why the difficulty of drawing the water, or any other weight, increases as it ascends nearer the top.

Charles. Then by diminishing the axis,

or by increasing the length of the handle advantage is gained?

Father. Yes, by either of those methods you may gain power, but it is very evident that the axis cannot be diminished beyond a certain limit, without rendering it too weak to sustain the weight; nor can the handle be managed, if it be constructed on a scale much larger than what is commonly used.

Charles. We must, then, have recourse to the wheel with spikes standing out of it at certain distances from each other to serve as levers.

Father. You may by this means increase your power according to your wish, but it must be at the expense of time, for you know that a simple handle may be turned several times, while you are pulling the wheel round once. To the principle of the *wheel and axis*, may be referred the capstan, windlass, and all those numerous kinds of cranes, which are to be seen at the different wharves on the banks of the Thames.

'd from repose, aloft the sailors swarm,
with their *levers* soon the *windlass* arm.
rder given, up-springing with a bound
lodge the bars, and wheel their en-
gines round:
ery turn the clanging pauls resound,
n reluctant from its oozy cave
ond'rous anchor rises o'er the wave.

FALCONER'S SHIPWRECK.

arles. I have seen a crane, which con- of a wheel large enough for a man to in.

ther. In this the weight of the man, en (for there are sometimes two or ,) is the moving power; for, as the steps forwards, the part upon which he s becomes the heaviest, and conse- tly descends till it be the lowest. On ame principle, you may see at the door any bird-cage makers, a bird, by its ht, give a wicker cage a circular mo- now, if there were a small weight nded to the axis of the cage, the bird s motion would draw it up, for as it from the bottom bar to the next, its *ntum* causes that to descend, and thus

the operation is performed, both with regard to the cage, and to those large cranes which you have seen.

Emma. Is there no danger if the man happen to slip?

Father. If the weight be very great, a slip with the foot may be attended with very dangerous consequences. To prevent which, there is generally fixed at one end of the axis a little wheel G, (Fig. 22.) called a ratchet-wheel; with a catch H, to fall in to its teeth; this will, at any time, support the weight in case of an accident. Sometimes, instead of men walking within the great wheel, cogs are set round it on the outside, and a small trundle wheel made to work in the cogs, and to be turned by a winch.

Charles. Are there not other sorts of cranes in which all danger is avoided?

Father. The crane is a machine of such importance to the commercial concerns of this country, that new inventions of it are continually offered to the public: I will, when we go to the library, show you in the

10th vol. of the Transactions of the Society for the Encouragement of Arts and Sciences, an engraving of a safe, and, I believe, truly excellent crane; it was invented by a friend of mine, Mr. James White, who possessed a most extraordinary genius for mechanics, and who formerly offered his services to a noble Duke, then at the head of the Board of Ordinance, but they being rejected, he went to the Continent, where he is very profitably exercising his talents.

Charles. But you said that this mechanical power might be considered as a lever of the first kind.

Father. I did; and if you conceive the wheel and axis (Fig. 22.) to be cut through the middle in the direction A B; F G B (Plate III. Fig. 23.) will represent a section of it. A B is a lever, whose centre of motion is C; the weight W, sustained by the rope A W, is applied at the distance C A, the radius of the axis; and the power P, acting in the direction B P, is applied at the distance C B, the radius of the wheel; therefore, according to the principle of the

lever, the power will balance the
when it is as much less than the wei
the distance C B is greater than the d
of the weight A C.

CONVERSATION XVIII.

Of the Pulley.

FATHER. The third mechanical power, the *pulley*, may be likewise explained on the principle of the lever. The line A B (Plate IV. Fig. 24.) may be conceived to be a lever, whose arms A C and B C are equal, and C the fulcrum, or centre of motion. If now two equal weights, W and P, be hung on the cord passing over the pulley, they will balance one another, and the fulcrum will sustain both.

Charles. This pulley then, like the common balance, gives no advantage.

Father. From the single *fixed* pulley no mechanical advantage is derived; it is, nevertheless of great importance in changing

the direction of a power, and is very used in buildings for drawing up weights, it being much easier for a m raise such burdens by means of a pulley, than to carry them up a long la

Emma. Why is it called a mech power?

Father. Though a single fixed gives no advantage, yet when it is not or when two or more are combine what is called a system of pulleys, the possess all the properties of the othe chanical powers. Thus in C D B (Pla Fig. 25.) C is the fulcrum, therefore a er P, acting at B, will sustain a weight W, acting at A, for B C is doul distance of A C from the fulcrum.

Again it is evident, in the presen that the whole weight is sustained cord E D P, and whatever sustains ha cord, sustains also half the weight; b half is sustained by the fixed hook E sequently the power at P has only the half to sustain, or in other words, any power at P will keep in equilibrio a weight at W.

Charles. Is the velocity of P double that of W?

Father. Undoubtedly; if you compare the space passed through by the hand at P with that passed by W, you will find that the former is just double of the latter, and therefore the *momenta* of the power and weight, as in the lever, are equal.

Charles. I think I see the reason of this, for if the weight be raised an inch, or a foot, both sides of the cord must also be raised an inch, or foot, but this cannot happen without that part of the cord at P passing through two inches, or two feet of space.

Father. You will now easily infer from what has been already shown of the single *moveable* pulley, that in a system of pulleys, the power gained must be estimated, by doubling the number of pulleys in the lower or moveable block. So that when the fixed block X (Plate IV. Fig. 26.) contains two pulleys which only turn on their axes, and the lower block *y* contains also two pulleys, which not only turn on their axes,

but also *rise* with the weight, the advantage is as four; that is, a single pound at P will sustain four at W.

Charles. In the present instance also I perceive, that by raising W an inch, there are four ropes shortened each an inch, and therefore the hand must have passed through four inches of space in raising the weight a single inch; which establishes the maxim, that what is gained in power is lost in space. But, papa, you have only talked of the power of balancing or sustaining the weight, something more must, I suppose, be added to raise it.

Father. There must; considerable allowance must likewise be made for the friction of the cords, and of the pivots, or axes, on which the pulleys turn. In the mechanical powers, in general, one-third of power must be added for the loss sustained by friction, and for the imperfect manner in which machines are commonly constructed. Thus, if by *theory* you gain a power of *600*; in *practice*, you must reckon only *upon 400*. In those pulleys which we have

been describing, writers have taken notice of three things, which take much from the general advantage and convenience of pulleys as a mechanical power. The *first* is, that the diameters of the axes, bear a great proportion to their own diameters. The *second* is, that in working they are apt to rub against one another, or against the side of the block. And the *third* disadvantage, is the stiffness of the rope that goes over and under them.

The first two objections have been, in a great degree, removed by the concentric pulley, invented by Mr. James White: B (Plate IV. Fig. 27.) is a solid block of brass, in which grooves are cut, in the proportion of 1, 3, 5, 7, 9, &c. and A is another block of the same kind, whose grooves are in the proportion of 2, 4, 6, 8, 10, &c. and round these grooves a cord is passed, by which means they answer the purpose of so many distinct pulleys, every point of which moving with the velocity of the string in contact with it, the whole friction is removed *to the two* centres of motion of the blocks

A and B; besides it is of no small advantage, that the pulleys being all of one piece there is no rubbing one against the others.

Emma. Do you calculate the power gained by this pulley, in the same method as with the common pulleys?

Father. Yes, for pulleys of every kind, the rule is general, the advantage gained is found by doubling the number of the pulleys in the lower block: in that before you there are six grooves, which answer to as many distinct pulleys, and consequently the power gained is twelve, or one pound at P will balance twelve pounds at W.

CONVERSATION XIX.

Of the Inclined Plane.

'ATHER. We may now describe the ned plane, which is the fourth mecha-l power.

harles. You will not be able, I think, duce this also to the principle of the r.

ather. No, it is a distinct principle, and writers on these subjects reduce at the six mechanical powers to two, viz. ever and inclined plane.

nma. How do you estimate the ad-ge gained by this mechanical power?

ther. The method is very easy, for as much as the length of the plane ex-s its perpendicular height, so much is

the advantage gained. Suppose A B (Plate IV. Fig. 28.) is a plane standing on the table, and C D another plane inclined to it; if the length C D be three times greater than the perpendicular height; then the cylinder E will be supported upon the plane C D, by a weight equal to the third part of its own weight.

Emma. Could I then draw up a weight on such a plane with a third part of the strength that I must exert in lifting it up at the end?

Father. Certainly, you might; allowance, however, must be made for overcoming the friction; but then you perceive, as in other mechanical powers, that you will have three times the space to pass over, or that as you gain power you will lose time.

Charles. Now I understand the reason why sometimes there are two or three strong planks laid from the street to the ground-floor warehouses, making therewith an inclined plane, on which heavy packages are raised or lowered.

Father. The inclined plane is chiefly

used for raising heavy weights to small heights, for in warehouses situated in the upper part of buildings, cranes and pulleys are better adapted for the purpose.

Charles. I have sometimes, papa, amused myself by observing the difference of time which one marble has taken to roll down a smooth board, and another which has fallen by its own gravity without any support.

Father. And if it were a long plank, and you took care to let both marbles drop from the hand at the same instant, I dare say you found the difference very evident.

Charles. I did, and now you have enabled me to account for it very satisfactorily, by showing me that as much more time is spent in raising a body along an inclined plane, than in lifting it up at the end, as that plane is longer than its perpendicular height. For I take it for granted that the rule holds in the ascent as well as in the descent.

Father. If you have any doubt remaining, *a few words will* make every thing

clear. Suppose your marbles placed on a plane, perfectly horizontal, as on this table, they will remain at rest wherever they are placed: now if you elevated the plane in such a manner that its height should be equal to half the length of the plane, it is evident from what has been shown before, that the marbles would require a force equal to half their weight to sustain them in any particular position: suppose then the plane perpendicular to the table, the marbles will descend with their whole weight, for now the plane contributes in no respect to support them, consequently they would require a power equal to their whole weight to keep them from descending.

Charles. And the swiftness with which a body falls is to be estimated by the force with which it is acted upon?

Father. Certainly, for you are now sufficiently acquainted with philosophy to know that the effect must be estimated from the cause. Suppose an inclined plane is thirty-two feet long, and its perpendicular height is sixteen feet, what time will a marble take

in falling down the plane, and also in descending from the top to the earth by the force of gravity?

Charles. By the attraction of gravitation, a body falls sixteen feet in a second (See p. 55.) therefore the marble will be one second in falling perpendicularly to the ground; and as the length of the plane is double its height, the marble must take two seconds to roll down it.

Father. I will try you with another example. If there be a plane 64 feet perpendicular height, and 3 times 64, or 192 feet long, tell me what time a marble will take in falling to the earth by the attraction of gravity, and how long it will be in descending down the plane.

Charles. By the attraction of gravity it will fall in two seconds; because, by multiplying the sixteen feet which it falls in the first second, by the square of two seconds (the time) or four, I get sixty-four the height of the plane. But the plane being three times as long as it is perpendicularly high, it must be three times as many seconds

in rolling down the plane, as it was in scending freely by the force of gravity, is, six seconds.

Emma.. Pray, papa, what common struments are to be referred to this me nical power, in the same way, as sciss pincers, &c. are referred to the lever?

Father. Chisels, hatchets, and whate other sharp instruments which are cham ed, or sloped down to an edge on one only, may be referred to the principle the inclined plane.

CONVERSATION XX.

Of the Wedge.

FATHER. The next mechanical power is the *wedge*, which is made up of the two inclined planes D E F G and C E F G (Plate IV. Fig. 29.) joined together at their bases E F G: D C is the whole thickness of the wedge at its back A B C D, where the power is applied, and D F and C F are the length of its sides; now there will be an equilibrium between the power impelling the wedge downward, and the resistance of the wood, or other substance acting against its sides, when the thickness D C of the wedge is to the length of the two sides, or, which is the same thing, when half the thickness

D E of the wedge at its back is to the length of D F one of its sides, as the power is to the resistance.

Charles. This is the principle of the inclined plane.

Father. It is, and notwithstanding all the disputes which the methods of calculating the advantage gained by the wedge have occasioned, I see no reason to depart from the opinion of those who consider the wedge as a double inclined plane.

Emma. I have seen people cleaving wood with wedges, but they seem to have no effect, unless great force and great velocity are also used.

Father. No, the power of the attraction of cohesion, by which the parts of wood stick together, is so great, as to require a considerable *momentum* to separate them. Did you observe nothing else in the operation worthy of your attention?

Charles. Yes, I also took notice that the wood generally split a little below the place to which the wedge reached.

Father. This happens in cleaving most

of wood, and then the advantage
by this mechanical power, must be
ortion as the length of the sides of
t in the wood is greater than the
of the whole back of the wedge.
are other varieties in the action of
lge; but, at present, it is not neces-
refer to them.

a. Since you said that all instru-
which sloped off to an edge on one
y, were to be explained by the prin-
the inclined plane; so, I suppose,
se which decline to an edge on both
must be referred to the principle of
lge.

er. They must, which is the case
any chisels, and almost all sorts of
c.

les. Is the wedge much used as a
ical power?

er. It is of great importance in a
riety of cases, in which the other
ical powers are of no avail; and
ises from the momentum of the
which is greater, beyond comparison,

than the application of any dead weig
pressure, such as is employed in the
mechanical powers. Hence it is us
splitting wood, rocks, &c. and ever
largest ship may be raised to a small h
by driving a wedge below it. It is
used for raising up the beam of a h
when the floor gives way, by reason o
great a burden being laid upon it.
usual also in separating large mill-s
from the siliceous sand-rocks in some
of Derbyshire to bore horizontal hole
der them in a circle, and fill these
pegs or wedges made of dry wood, w
gradually swell by the moisture of
earth, and in a day or two lift up the
stone without breaking it; to this pr
Dr. Darwin alludes:

Climb the rude steeps, the granite-cliffs surrou
Pierce with steel points, with wooden *wedges* wo

BOTANIC GA

CONVERSATION XXI.

Of the Screw.

FATHER. Let us now examine the properties of the sixth and last mechanical power, the *screw;* which, however, cannot be called a simple mechanical power, since it is never used without the assistance of a lever or winch; by which it becomes a compound engine, of great power in pressing bodies together, or in raising great weights. A B (Plate IV. Fig. 30.) is the representation of one, together with the lever D F.

Emma. You said just now, papa, that all the mechanical powers were reducible *either to the lever* or inclined plane, how *can the screw* be referred to either?

Father. The screw is composed of two parts, one of which A B is called the screw, and consists of a spiral protuberance, called the *thread*, which may be supposed to be wrapt round a cylinder; the other part C D, called the *nut*, is perforated to the dimensions of the cylinder; and in the internal cavity is also a spiral groove adapted to receive the thread. Now if you cut a slip of writing-paper in the form of an inclined plane *a b c*, (Fig. 30.) and then wrap it round a cylinder of wood, you will find that it makes a spiral answering to the spiral part of the screw; moreover, if you consider the ascent of the screw, it will be evident that it is precisely the ascent of an inclined plane.

Charles. By what means do you calculate the advantage gained by the screw?

Father. There are, at first sight, evidently two things to be taken into consideration; the first is the distance between the threads of the screw;—and the second is *the length of* the lever.

Charles. Now I comprehend pretty clear-

ly how it is an inclined plane, and that its ascent is more or less easy as the threads of the spiral are nearer or farther distant from each other.

Father. Well then, let me examine by a question, whether your conceptions be accurate; suppose two screws, the circumferences of whose cylinders are equal to one another; but in one, the distance of the threads to be an inch apart; and that of the threads of the other only one-third of an inch; what will be the difference of the advantage gained by one of the screws over the other?

Charles. The one whose threads are three times nearer than those of the other, must, I should think, give three times the most advantage.

Father. Give me the reason for what you assert.

Charles. Because, from the principle of the inclined plane, I learnt that if the *height* of two planes were the same, but the length of one, twice, thrice, or four times greater than that of the other, the mechanical ad-

Charles. I do;—it may be done either by taking a longer lever, or by diminishing the distance of the threads of the screw.

Father. Tell me the result then, supposing the threads of the screw so fine as to stand at the distance of but one quarter of an inch asunder; and that the length of the lever were 8 feet instead of 7.

Charles. The circumference of the circle made by the lever will be 8 multiplied by 6, equal to 48 feet or 576 inches, or 2304 quarter inches, and as the elevation of the screw is but one quarter of an inch, the space passed by the power, will, therefore, be 2304 times greater than that passed by the weight, which is the advantage gained in this instance.

Father. A child then capable of moving the lever sufficiently to overcome the friction, with the addition of a power equal to one pound, will be able to raise 2304 pounds, or something more than 20 hundred weight and a half. The strength of a powerful man would be able to do 20 or 30 times as much more.

Charles. But I have seen at Mr. W——'s paper-mills, to which I once went, six or eight men use all their strength in turning a screw, in order to press out the water of the newly made paper. The power applied in that case must have been very great indeed.

Father. It was; but I dare say that you are aware that it cannot be estimated, by multiplying the power of one man by the number of men employed.

Charles. That is, because the men standing by the side of one another, the lever is shorter to every man the nearer he stands to the screw, consequently though he may exert the same strength, yet it is not so effectual in moving the machine, as the exertion of him who stands nearer to the extremity of the lever.

Father. The true method, therefore, of calculating the power of this machine, aided by the strength of these men, would be to estimate accurately the power of each man according to his position, and then ad-

ding all these separate advantages together for the total power gained.

Emma. A machine of this kind, is, I believe, used by book-binders, to press the leaves of the books together before they are stitched?

Father. Yes, it is found in every book-binder's work-shop, and is particularly useful where persons are desirous of having small books reduced to a still smaller size for the pocket. It is also the principal machine used for coining money;—for taking off copper-plate prints; and for printing in general.

Charles. I remember Dr. Darwin's description of coining.

With iron lips his rapid rollers seize
The lengthning bars, in thin expansion squeeze;
Descending *screws* with pond'rous fly-wheels wound
The tawny plates, the new medallions round;
Hard dies of steel the cupreous circles cramp,
And with quick fall his massy hammers stamp.
The Harp, the Lily, and the Lion join,
And GEORGE, and BRITAIN guard the sterling coin.

BOTANIC GARDEN.

Father. These lines are descriptive of Mr. Boulton's magnificent apparatus for coining; the whole machinery is worked by an improved steam-engine, which rolls the copper for half-pence; works the screw-presses for cutting out the circular pieces of copper; and coins both the faces and edges of the money at the same time: and since the circulation of the new half-pence, we are all acquainted with the superior excellence of the workmanship. By this machinery, four boys of ten or twelve years old, are capable of striking 30,000 guinies in an hour, and the machine itself keeps an unerring account of the number of pieces struck.

Emma. And I have seen the cyder-press in Kent, which consists of the same kind of machine.

Father. It would, my dear, be an almost endless task, were we to attempt to enumerate all the purposes to which the screw is applied in the mechanical arts of

life; it will, perhaps, be sufficient to tell you, that wherever great pressure is required, there the power of the screw is uniformly employed.

OF ASTRONOMY.

CONVERSATION XXII.

OF THE FIXED STARS.

Tutor—Charles—James.

CHARLES. The delay occasioned by our unusually long walk, has afforded us one of the most brilliant views of the heavens that I ever saw.

James. It is uncommonly clear, and the longer I keep my eyes fixed upwards, the more stars seem to appear: how is it possible to number these stars? and yet I have heard that they are numbered, and *even arranged in* catalogues according to

their apparent magnitudes. Pray sir, explain to us how this business was performed.

Tutor. This I will do, with great pleasure, some time hence, but at present, I must tell you that in viewing the heavens with the naked eye, we are very much deceived as to the supposed number of stars that are at any time visible. It is generally admitted, and on good authority too, that there are never more than one thousand stars visible to the sight, unassisted by glasses, at any one time, and in one place.

James. What! can I see no more that a thousand stars if I look all round the heavens? I should suppose there were millions.

Tutor. This number is certainly the limit of what you can at present behold; and that which leads you, and persons in generel, to conjecture that the number is so much larger, is owing to an optical deception.

James. Are we frequently liable to be deceived by our senses?

Tutor. We are, if we depend on them *singly*; but where we have an opportunity

ing in the assistance of one sense to of another, we are seldom subject to convenience.

les. Do you not know that if you small marble in the palm of the left and then cross the second finger of ht hand over the first, and in that po- with your eyes shut, move the mar- h those parts of the two fingers at which are not accustomed to come in- tact with any object at the same hat the one marble will appear to the as two? In this instance, without the ice of our eyes, we should be deceiv- the sense of feeling.

r. This is to the point, and shows e judgement formed by means of a sense is not always to be depended

es. I recollect the experiment very ve had it from papa, a great while But that has nothing to do with the idgement which we are said to form the number of stars.

Tutor. You are right; it does not
diately concern the subject before us,
may be useful as affording a lesson c
desty, by instructing us that we ought
close our minds against new evidenc
may be offered upon any topic, nc
standing the opinions we may have a
formed. You say, that you see mill
stars, whereas the ablest astronomers
that with the naked eye you cannot
time see so many as a thousand.

Charles. I should indeed have t
with my brother, had you not assert
contrary; and I am anxious to kno
the deception happens, for I am sur
must be a great deception somewhe
do not at this time behold very many
sands of stars in the heavens.

Tutor. You know that we see
only by means of the rays of light
proceed from them in every directior
you must for the present, give me
when I tell you that the distance of t
ed stars from us is immensely great,
quently the rays of light have to tra

tance, in the course of which, especially their passage through our atmosphere, y are subject to numberless *reflections*, l *refractions*. By means of these, other s of light come to the eye, every one of ich, perhaps, impresses upon the mind idea of so many separate stars. Hence es that optical fallacy by which we are to believe the stars which we behold are umerable.

ames. I should like to see an experiment to confirm this.

Tutor. I have no objection: in every case ought to require the best evidence that subject will admit of:

To ask or search I blame thee not, for heaven
Is as the book of God before the set,
Wherein to read his wonderous works, and learn
His seasons, hours, or days, or months, or years.
MILTON.

vill show you two experiments which go a good way to remove the difficulty. , for this *purpose*, *we* must step into the e.

Here are two common looking-glasses, which, philosophically speaking, are *plain mirrors*. I place them in such a manner on the table that they support one another from falling by meeting at the top. I now place this half-crown between them, on a book, to to raise it a little above the table. Tell me how many pieces of money you would suppose there were, if you did not know that I had used but one.

James. There are several in the glasses.

Tutor. I will alter the position of the glasses a little, by making them almost parallel to one another; now look into them, and say what you see.

James. There are more half-crowns now than there were before.

Tutor. It is evident, then, that by *reflection* only, a single object, for I have made use of but one half-crown, will give you the idea of a vast number.

Charles. If a little contrivance had been used to conceal the method of making the experiment, I should not have believed but that there had been several half-crowns instead of one.

Tutor. Bring me your multiplying glass; look through it at the candle: how many do you see? or rather how many candles should you suppose there were, did you not know that there was but one on the table?

James. A great many, and a pretty sight it is.

Charles. Let me see; yes, there are: but I can easily count them; there are sixteen.

Tutor. There will be just as many images of the candle, or any other object at which you look, as there are different surfaces on your glass. For by the principal of *refracton*, the image of the candle is seen in as many different places as the glass has surfaces; consequently, if instead of 16 there had been 60, or, if they could have been cut and polished so small, 600, then the single candle would have given you the idea of 60, or 600. What think you now about the stars?

James. Since I have seen that *reflection* and *refraction* will each, singly, afford such optical *deceptions*, I can no longer doubt, *but that, if both* these causes are combined *you say they* are with respect to the rays

of light coming from the fixed stars, a thousand real luminaries may have the power of exciting in my mind the idea of millions.

Tutor. I will mention another experiment, for which you may be prepared against the next clear star-light night. Get a long narrow tube, the longer and narrower the better, provided its weight does not render it unmanageable: examine through it any one of the largest fixed stars; which are called stars of the *first* magnitude, and you will find that though the tube takes in as much sky as would contain many such stars, yet that the single one at which you are looking, is scarcely visible, by the few rays which come *directly* from it: this is another proof that the brilliancy of the heavens is much more owing to *reflected* and *refracted* light, than to the direct rays flowing from the stars.

CONVERSATION XXIII.

Of the Fixed Stars.

CHARLES. Another beautiful evening presents itself; shall we take the advantage which it offers of going on with our astronomical lectures?

Tutor. I have no objection, for we do not always enjoy such opportunities as the brightness of the present evening affords.

James. I wish very much to know how to distinguish the stars, and to be able to call them by their proper names.

Tutor. This you may very soon learn; a few evenings, well improved, will enable you to distinguish all the stars of the first magnitude which are visible, and all the relative positions of the different constellations.

James. What are constellations,

Tutor. The ancients, that they m
better distinguish and describe th
with regard to their situation in t
vens, divided them into constellatio
is, systems consisting of such stars
near to each other, giving them th
of such men or things, as they fanc
space which they occupied in the l
represented.

Charles. Is it then perfectly ai
that one collection is called the *gre*
another *the dragon;* a third *Hercu*
so on?

Tutor. It is; and though the
been additions to the number of
each constellation, and various new
lations invented by modern astro
yet the original division of the st
these collections, was one of those f
trary inventions which has descend
out alteration, otherwise than by a
from the days of Ptolemy down to
sent time.—Do you know how to

four Cardinal points, as they are usually called, the North, South, West, and East?

James. O yes, I know that if I look at the sun at twelve o'clock, or at noon, I am also looking to the south where he then is; my back is towards the north; the west is on my right hand, and the east on my left.

Tutor. But you must learn to find these points without the assistance of the sun, if you wish to be a young astronomer.

Charles. I have often heard of the *north pole star;* that will perhaps answer the purpose of the sun, when he has left us.

Tutor. You are right; do you see those seven stars which are in the constellation of the *Great Bear;* some people have supposed their position will aptly represent a *plough;* others say, that they are more like a *waggon and horses;*—the four stars representing the body of the waggon, and the other three the horses, and hence they are called by some the plough, and by others they are called Charles's wain or waggon. Here is a drawing of it: (Plate v. Fig. 1.) *a b d g*

represents the four stars, and *c* z B the c
three.

Charles. What is the star P?

Tutor. That presents the polar st
which you just now alluded; and you
serve, that if a line were drawn through
stars *b*, and *a*, and produced far enoug
would nearly touch it.

James. Let me look in the heavens
it by this guide. There it is, I suppos
shines with a steady, and rather dead
of light, and it appears to me, that it w
be a little to the right of the line pa
through the stars *b* and *a*.

Tutor. It would and these stars are
erally known by the name of the *poin*
because they point to *p* the north pole, w
is situated a little more than two degrees
the star P.

Charles. Is that star always in the s
part of the heavens?

Tutor. It may be considered as unif
ly maintaining its position, while the c
stars seem to move round it as a centre.
shall have occasion to refer to this star ag

esent, I have directed your attention to a proper method of finding the Cardi- oints by star-light.

mes. Yes, I understand now, that if I to the north, by standing with my face at star, the south is at my back, on my hand is the east, and the west on my

tor. This is one important step in our nomical studies; but we can make use ese stars as a kind of standard, in or- o discover the names and positions of s in the heavens.

arles. In what way must we proceed is business?

tor. I will give you an example or conceive a line drawn from the star Z, ng B a little to the left, and it will pass igh that very brilliant star A near the on towards the west.

mes. I see the star, but how am I to v its name?

utor. Look on the celestial globe for tar Z, and suppose the line drawn on globe, as we conceived it done in the

heavens, and you will find the star, and its name.

Charles. Here it is;—its name is Arcturus.

Tutor. Take the figure, (Fig. 1.) and place Arcturus at A, which is its relative position, in respect to the constellation of the Great Bear. Now, if you conceive a line drawn through the stars *g* and *b*, and extended a good way to the right, it will pass just above another very brilliant star. Examine the globe as before, and find its name.

Charles. It is *Capella*, the *goat*.

Tutor. Now, whenever you see any of these stars, you will know where to look for the others without hesitation.

James. But do they never move from their places?

Tutor. With respect to us, they seem to move together with the whole heavens. But they always remain in the same relative position, with respect to each other. Hence, they are called *fixed* stars, in opposition to the *planets*, which, like our earth, are con-

ly changing their places, both with
l to the fixed stars, and to themselves

rles. I now understand pretty well
ethod of acquiring a knowledge of the
and places of the stars.

er. And with this, we will put an end
present conversation.

CONVERSATION XXIV

Of the Fixed Stars, and Ecliptic.

TUTOR. I dare say that y
have no difficulty in finding the no
star as soon as we go into the open

James. I shall at once know
look for that and the other stars wl
pointed out last night, if they l
changed their places.

Tutor. They always keep tl
position, with respect to each other
their situation, with regard to the
will be different at different season
year, and in different hours of tl
Let us go into the garden.

Charles. The stars are all in
place as we left them last evening

sir, if we conceive a straight line drawn through the two stars in the plough, which, in your figure (Fig. 1.) are marked *d* and *g*, and to extend a good way down, it will pass, or nearly pass through a very bright star, though not so bright as *Arcturus* or *Capella*, what is that called?

Tutor. It is a star of the second magnitude, and if you refer to the celestial globe, in the same way as you were instructed last night, you will find it is called *Regulus*, or *Cor Leonis*, the *Lion's heart*. By this method you may quickly discover the names of all the principal stars, and afterwards with a little patience, you will easily distinguish the others, which are less conspicuous.

Charles. But they have not all names; how are they specified?

Tutor. If you look on the globe, you will observe, that they are distinguished by the different letters of the Greek alphabet; and in those constellations, in which there are stars of *different* apparent magnitudes, *the largest is* α alpha, the next in size β beta,

the third γ gamma, the fourth δ delta, and so on.

James. Is there any particular reason for this?

Tutor. The adoption of the characters of the Greek alphabet, rather than any other, was perfectly arbitrary; it is, however, of great importance, that the same characters should be used in general by astronomers of all countries, for by this means the science is in possession of a sort of universal language?

Charles. Will you explain how this is?

Tutor. Suppose an astronomer in North America, Asia, or any other part of the earth, observe a comet in that part of the heavens were the constellation of the *plough* is situated, and he wishes to describe it to his friend in Great Britain, in order that he may know, whether it was seen by the inhabitants of this island. For this purpose, he has only to mention the time when he discovered it; its position, as nearest to some one of the stars, calling it by the Greek letter by which it is designated; and

course which it took from one star to-
ds another. Thus he might say, that
such a time he saw a comet near δ in the
at Bear, and that its course was directed
n δ to β, or any other, as it happens.

harles. Then, if his friend here had
a comet at the same time, he would,
this means know, whether it was the
e or a different comet?

utor. Certainly, and hence you per-
e of what importance it is, that astrono-
s in different countries should agree to
k the same stars and systems of stars
the same characters. But to return to
star, to which you just called my at-
ion, the *cor leonis,* it is not only a re-
kable star, but its position is also re-
kable, it is situated in the *ecliptic.*

ames. What is that, sir?

Tutor. The *ecliptic* is an imaginary great
le in the heavens, which the sun *appears*
describe in the course of a year. If you
k on the celestial globe, you will see it
rked with a *red* line, perhaps an emblem

of the fierce heat communicated to t
that body.

James. But the sun seems to ha
circular motion in the heavens every d

Tutor. It does; and this is calle
apparent *diurnal*, or daily motion, whi
very different from the path it appea
traverse in the course of a year. Th
mer is observed by the most inatte
spectator, who cannot but know, tha
sun is seen every morning in the Ea
noon in the South, and in the eveni
the West; but the knowledge of the
must be the result of patient observati

Charles. And what is the *green*
which crosses it?

Tutor. It is called the *Equator;* t
an imaginary circle belonging to the
which you must take for granted, a
longer, is of a globular form. If you
conceive the plane of the terrestrial
tor to be produced to the sphere o
fixed stars, it would mark out a circ
the heavens, called the *celestial equat*

equinoctial, which would cut the *ecliptic* in two parts.

James. Can we trace the circle of the *ecliptic* in the heavens?

Tutor. It may be done with tolerable accuracy by two methods; *first*, by observing several remarkable fixed stars, to which the moon in its course seems to approach. The *second* method is by observing the places of the planets.

Charles. Is the moon then always in the ecliptic?

Tutor. Not exactly so; but it is always either in the ecliptic, or within five degrees and a third of it on one side or the other. The planets also, by which I mean, Mercury, Venus, Mars, Jupiter, Saturn, and the Herschel, are never more than eight degrees distant from the line of the ecliptic.

James, How can we trace this line, by help of the fixed stars?

Tutor. By comparing the stars in the heavens, with their representatives on the artificial *globe*, a practice which may be *easily acquired*, as you have seen. I will

mention to you the names of those stars, and you may first find them on the globe, and then refer to as many of them as are now visible in the heavens. The first is in the *Ram's* horn called *α Arietas*, about ten degrees to the *north* of the ecliptic; the second is the *star Aldebaran* in the Bull's eye, six degrees *south* of the ecliptic.

Charles. Then if at any time I see these two stars, I know that the ecliptic runs between them, and nearer to Aldebaran, than to that in the Ram's horn.

Tutor. Yes: now carry you eye eastward to a distance somewhat greater from Aldebaran, than that is east of *α* Arietis, and you will perceive two bright stars at a small distance from one another called *Castor* and *Pollux;* the lower one, and that which is least brilliant, is Pollux, seven degrees on the north side of the ecliptic. Following the same track, you will come to *Regulus*, or the *cor leonis*, which I have already observed is exactly in the line of the ecliptic. Beyond this, and only two degrees south of that line, you will find the

beautiful star in the virgin's hand, called *Spica Virginis*. You then arrive at *Antares*, of the *Scorpion's heart*, five degrees on the same side of the ecliptic. Afterwards you will find *α Aquilæ*, which is situated nearly thirty degrees north of the ecliptic; and farther on is the star *Fomahaut* in the fish's mouth, about as many degrees south of that line. The ninth and last of these stars is *Pegasus*, in the wing of the flying-horse, which is north of the ecliptic nearly twenty degrees.

James. Upon what account are these nine stars particularly noticed?

Tutor. They are selected as the most conspicuous stars near the moon's orbit, and are considered as proper stations, from which the moon's distance is calculated for every three hours of time: and hence are constructed those tables in the *Nautical Almanac*, by means of which Navigators, in their most distant voyages, are enabled to estimate, on the trackless ocean, the particular part of the globe on which they are.

Tutor. You must; or some other book of the same kind, if you would proceed on the best and most rational plan. Besides, when you know the use of this book, which you will completely with half an hour's attention, you have nothing more to do in order to find the position of the planets at any day of the year, than to turn to that day in the Ephemeris, and you will instantly be directed to those parts of the heavens in which the different planets are situated. Turn to the second page.

Charles. Here the astronomical characters are explained.

Tutor. The first twelve are the representatives of the signs into which the circle of the ecliptic is divided, called also the twelve signs of the *Zodiac*.

♈ Aries.	♌ Leo.	♐ Sagittarius.
♉ Taurus.	♍ Virgo.	♑ Capricorn.
♊ Gemini.	♎ Libra.	♒ Aquarius.
♋ Cancer.	♏ Scorpio.	♓ Pisces.

Every circle connected with this subject is supposed to be divided into 360 parts, called degrees, and since that of the ecliptic is also divided into 12 signs, each sign must contain 30 degrees. Astronomers subdivide each degree into minutes and seconds, thus if I would express an angle of 25 degrees, 11 minutes and 45 seconds, I should write $25^{\circ}..11'..45''$. Or, if I would express the situation of the sun for the first of January, 1800, I look into the Ephemeris and find it in Capricorn, or ♑ $10^{\circ}..56'..38''$.

James. What do you mean by the Zodiac?

Tutor. It is an imaginary broad circle or belt surrounding the heavens, about sixteen degrees wide; along the middle of which runs the ecliptic. The term Zodiac is derived from a Greek word signifying an animal, because each of the twelve signs formerly represented some animal; that which we now call Libra, being by the ancients reckoned a part of Scorpio.

James. Why are the signs of the Zodiac called by the several names of Aries, Taurus, Leo, &c. I see no likeness in the heavens to Rams, or Bulls, or Lions, which are the English words for those Latin ones.

Tutor. Nor do I; nevertheless, the ancients saw, by the help of a strong imagination, a similarity between those animals, and the places which certain systems of stars took up in the heavens, and gave them the names which have continued to this day.

Charles. Perhaps these were originally invented, in the same way as we sometimes figure to our imagination, the appearances of men, beasts, ships, trees, &c. in the flying clouds or in the fire.

Tutor. They might possibly have no better authority for their origin. At any rate it will be useful for you to have the names of the twelve signs in your memory, as well as the order in which they stand: I will therefore repeat some lines written

Dr. Watts, in which they are expressed in English, and will be easily remembered :

> The *Ram*, the *Bull*, the *heavenly Twins*,
> And next the *Crab*, the *Lion* shines,
> The *Virgin* and the *Scales* ;
> The *Scorpion*, *Archer*, and Sea-*Goat*,
> The *Man* that holds the *watering pot*,
> And *Fish* with glittering tails.

Charles. We come now to the characters placed before the planets.

Tutor. These, like the former, are but a kind of short-hand characters, which, it is esteemed easier to write, than the names of the planets at length. They are as follow.

♅ The Herschel.	☉ The Sun.
♄ Saturn.	♀ Venus.
♃ Jupiter.	☿ Mercury.
♂ Mars.	☽ The Moon.
⊕ The Earth.	

With the other characters you have no need to trouble yourselves, till you come to calculate eclipses, and construct astronomical tables, a labour which may be deferred for

some years to come. Turn to the eighth page of the Ephemeris.

James. Have we no concern with the intermediate pages between the second and eighth?

Tutor. They do not contain any thing that requires explanation. In the eighth page, after the common almanac for January, the first two columns point out the exact time of the sun's rising and setting at London: thus on the 10th day of January he rises at 58 minutes after 7 in the morning, and sets at 2 minutes past 4 in the afternoon. The third column gives the *declination* of the sun.

James. What is that, sir?

Tutor. The *declination* of the sun, or of any heavenly body, is its distance from the imaginary circle in the heavens, called the *equinoctial.* Thus you observe that the sun's declination on the first of January is 23°. . 4′ south; or, it is so many degrees south of the imaginary *equator.* Turn to *March 1803*, and you will see that between the 20th and 21st days it is in the equator,

for at 12 o'clock at noon on the 20th it is only 25′ south, and at the same hour on the 21st it is 1′ north of that line: and when it is in the equator, then it has no declination.

Charles. Do astronomers always reckon from 12 o'clock at noon?

Tutor. They do: and hence the astronomical day begins 12 hours *later* than the day to according to common reckoning: and therefore the declination, longitude, latitude, &c. of the sun, moon, and planets, are always put down for 12 o'clock at noon of the day to which they are opposite. Thus the sun's declination for the 16th of January at 12 o'clock is 20°. . 56′ south.

Charles. Is that because it is the commencement of the astronomical day, though in common life it be called 12 o'clock?

Tutor. It is. The three next columns contain the moon's declination, the time of her rising and setting, and the time of her *southing, or when she* comes to the *meridian or south part of* the heavens.

Charles. Does she not come to the south at noon as well as the sun?

Tutor. No; the moon never comes to the meridian at the same time as the sun, but at the time of *new* moon. And this circumstance takes place at every new moon, as you may see by casting your eye down the several columns in the Ephemeris which relate to the moon's southing.

The glory, the changes, and the motion of the moon, are beautifully described in the following lines:

By thy command the Moon, as day-light fades,
Lifts her broad circle in the deep'ning shades;
Array'd in glory, and enthron'd in light,
She breaks the solemn terrors of the night;
Sweetly inconstant in her varying flame,
She changes still, another, yet the same!
Now in decrease, by slow degrees she shrouds
Her fading lustre in a veil of clouds;
Now of increase, her gath'ring beams display
A blaze of light, and give a paler day;
Ten thousand stars adorn her glitt'ring train,
Fall when she falls, and rise with her again;

And o'er the deserts of the sky unfold
Their burning spangles of sidereal gold:
Through the wide heav'ns she moves serenely
bright,
Queen of the gay attendants of the night;
Orb above orb in sweet confusion lies,
And with a bright disorder paints the skies.

BROOME.

James. What do you say of the 7th column;—*the clock before the sun?*

Tutor. A full explanation of that must be deferred till we come to speak of the *equation of time;* at present it will be sufficient for you to know that if you are in possession of a very accurate and well regulated clock, and also of an excellent sun-dial, they will be together only four days in a year; now this 7th column in the Ephemeris points out how much the clock is before the sun; or the sun before the clock for every day in the year. On *twelfth-day*, 1809, for instance, the clock is faster than the sun by six minutes and twelve seconds: but if you turn to *May-day* you will find that the clock is 3′. . 4″ slower than *the sun.*

James What are the four days in the years when the clock and dial are together?

Tutor. About the 15th of April; the 15th of June; the first of September; and Christmas-day.

Charles. By this table then we may regulate our clocks and watches.

James. In what manner?

Charles. Examine on any particular day the clock or watch, and dial at the same time, say 12 o'clock, and observe whether, the difference between them answers to the difference set down in the table, opposite to the day of observation. Thus on the 12th of March, 1809, the clock will not show true time unless it be 10′. . 3″ before the dial, or when the dial is 12 o'clock it must be 10′. . 3″ past 12 by the clock or watch.

Tutor. Well, let us proceed to the next page. The first three *short* columns, relating only to the duration of day-light and twilight, require no explanation: the fourth we shall pass over for the present; and the

remaining five give the *latitude* of the planets.

James. What do you mean by the latitude, sir?

Tutor. The latitude of any heavenly body is its distance from the *ecliptic* north or south. The latitude of *Venus*, on new-year's day, 1803, is 4° north.

Charles. Then the *latitude* of heavenly bodies, has the same refereuce to the *ecliptic*, that *declination* has to the equator?

Tutor. It has.

James. But I do not see any table of the sun's latitude.

Tutor. I dare say your brother can give you a reason for this.

Charles. Since the latitude of a heavenly body is its *distance from* the ecliptic, and since the sun is always in the ecliptic, therefore he can have no latitude.

Tutor. The *longitude* of the sun and planets is the only thing in this page that remains to be explained. The longitude of a heavenly body is its distance from the *first point of the* sign Aries, and it is mea-

sured on the ecliptic. It is usual, however, as you observe in the Ephemeris, to express the longitude of a heavenly body by the degree of the sign in which it is. In this way the sun's longitude on the first of January, 1809, is in Capricorn 10°. . 45'. 14"; that of the moon in Cancer, 6°. . 4'; that of Jupiter is in Pisces, 13°. . 35'.

Charles. There are some short columns at the bottom of the former page that you have omitted.

Tutor. The use of these will be better understood when we come to converse respecting the planets.*

* For the explanation of Heliocentric Longitude, see Conversation XLI.

CONVERSATION XXVI.

Of the Solar System.

TUTOR. We will now proceed to the description of the *Solar System.*

James. Of what does that consist, sir?

Tutor. It consists of the sun, and planets, with their satellites or moons. It is called the *Solar System*, from *Sol* the sun, because the sun is supposed to be fixed in the centre, while the planets, and our earth among them, revolve round him at different distances.

Charles. But are there not some people who believe that the sun goes round the *earth?*

Tutor. Yes, it is an opinion embrace the generality of persons, not accust to reason on these subjects. It was a ed by Ptolemy, who supposed the perfectly at rest, and the sun, planets fixed stars to revolve about it every tw four hours.

James. And is not that the most n supposition?

Tutor. If the sun and stars were bodies in comparison of the earth, and situated at no very great distance fr then the system maintained by Ptolem his followers might appear the most p ble.

James. Are the sun and stars very bodies then?

Tutor. The sun is more than a m of times larger than the earth which v habit, and many of the fixed stars are bably much larger than he is.

Charles. What is the reason, then, they appear so small?

Tutor. This appearance is caused b immense distance there is between u

these bodies. It is known with certainty, that the sun is more than 95 millions of miles distant from the earth, and the nearest fixed star is probably more than two hundred thousand times farther from us than even the sun himself.*

Charles. But we can form no conception of such distances.

Tutor. We talk of millions, with as much ease as of hundreds or tens, but it is not, perhaps, possible for the mind to form any adequate conceptions of such high numbers. Several methods have been adopted to assist the mind in comprehending the vastness of these distances. You have some idea of the swiftness with which a cannon-ball proceeds from the mouth of the gun?

James. I have heard at the rate of eight miles in a minute.

* The young reader will, when he is able to manage the subject, see this clearly demonstrated by a series of propositions in the 5th book of Dr. Enfield's Institutes of Natural Philosophy. Second Edition. See p. 346 to end of book V.

tor. And you know how many minutes are in a year?

mes. I can easily find that out, by plying 365 days by 24 for the number urs, and that product by 60, and I shall the number of minutes in a year, number is 525,600.

tor. Now if you divide the distance sun from the earth by the number of es in a year multiplied by 8, because nnon-ball travels at the rate of 8 miles minute, and you will know how long ody issuing from the sun, with the velo- of a cannon-ball, would employ in ing the earth.

rles. If I divide 95,000,000 by 525, multiplied by 8 or 4,204,800, the an- will be more than 22, the number of taken for the journey.

tor. Is is then probable that bodies so and at such distances from the earth, l revolve round it every day?

rles. I do not think it is.—Will you, on with the description of the *Solar n*?

Tutor. According to this system, the sun n the centre, about which the planets re- ve from *west to east*, according to the er of the signs in the ecliptic; that is, if lanet is seen in Aries, it advances to urus, then to Gemini, and so on.

James. How many planets are there be- ging to the sun?

Tutor. There are seven, besides some aller bodies of the same kind discovered thin these nine years. C (Plate v. Fig. represents the sun, the nearest to which *rcury* revolves in the circle *a*; next to n is the beautiful planet *Venus*, who per- ms her revolution in the circle *b*; then me the *Earth* in *t*; next to which is *Mars e*; then *Jupiter* in the circle *f*; afterwards *turn* in *g*; and far beyond him the *Her- hel* planet performs his revolution in the cle *h*. Do you recollect the lines in omson's Summer?

——————and thou, O Sun;
ul of surrounding worlds! in whom best seen
ines out thy MAKER! may I sing of thee?

'Tis by thy secret, strong attractive force,
As with a chain indissoluble bound,
Thy system rolls entire: from the far bourne
Of utmost *Herschel*, wheeling wide his round
Of *fourscore* years; to Mercury, whose disk
Can scarce be caught by philosophic eye,
Lost in the near effulgence of thy blaze.

Charles. You have substituted the words Herschel, and fourscore, for Saturn and thirty. These lines are descriptive of the figure.

James. For what are the smaller circles which are attached to several of the larger ones intended?

Tutor. They are intended to represent the *orbits* of the several satellites or moons belonging to some of the planets.

James. What do you mean by the word orbit?

Tutor. The path described by a planet in its course round the sun, or by a moon round its primary planet, is called its *orbit.* Look to the orbit of the earth in *t* (Fig. 2.) and you will see a little circle which repre-

sents the orbit in which our moon performs its monthly journey.

Charles. Has neither *Mercury* nor *Venus* any moon?

Tutor. None have ever been discovered belonging either to Mercury, Venus, or Mars. Jupiter, as you observe by the figure, has four moons: Saturn has seven: and the Herschel (which also goes by the name of the Georgium Sidus) has six; these for want of room are not drawn in the plate.

Charles. The *Solar System* then consists of the sun as the centre, round which revolve *seven* planets, and *eighteen* satellites or moons. Are there no other bodies belonging to it?

Tutor. Yes, as I just observed, four other planetary bodies have been very lately discovered as belonging to the solar system. These are very small, and named from the gentlemen who descovered them, who were Messrs. Piazzi, Olbers, and Harding. They are also called the *Ceres Ferdinandea*, *Pallas*, *Juno*, and *Vesta*. There are comets also which make their appearance occasion-

...ily ... and it would be wrong to...firm, that there can be no other ... belonging to the Solar System: since besides the four bodies just mentioned, only within these thirty years the seventh or the Herschel has been known to exist as a planet connected with the system.

Charles. Who first adopted the ... of the world which you have been describing?

Tutor. It was conceived and taught by Pythagoras to his disciples, 500 years before the time of Christ. But it seems to have been disregarded, or perhaps totally rejected, till about 300 years ago it was revived by Copernicus, and at length generally adopted by men of science:

> The sun revolving on his axis turns,
> And with creative fire intensely burns;
> Impell'd the forcive air, our earth supre...
> Rolls with the planets round the solar g...
> First Mercury completes his transient y...
> Glowing refulgent, with reflected glare

Bright Venus occupies a wider way;
The early harbinger of night and day:
More distant still our globe terraqueous turns,
Nor chills intense, nor fiercely heated burns.
Around her rolls the lunar orb of light,
Trailing her silver glories through the night:
Beyond our globe the sanguine Mars displays
A strong reflection of primeval rays;
Next belted Jupiter far distant gleams,
Scarcely enlighten'd with the solar beams;
With four unfix'd receptacles of light
He tow'rs majestic thro' the spacious height;
But farther yet the tardy Saturn lags,
And seven attendant luminaries drags;
Investing with a double ring his pace,
He circles through immensity of space.

CHATTERTON.

: the surface of the sea to be a flat

s. We should, I think, see the ip at once, that is, the hull would as soon as the top-mast.

It certainly must, or indeed rather ecause the body of the vessel being larger than a slender mast, it must y be visible at a greater distance.

Yes, I can see the steeple of a t a much greater distance than I rn the iron conductor which is and that I can perfectly see long e little piece of gold wire, which t its extremity, is visible.

Well, but the top-mast of a vessel lways in view some little time be-ull of the vessel can be discerned. the surface of the sea be globular, t to be the appearance, because berence or swelling of the water he vessel, and the eye of the spec-l hide the body of the ship some *the* pendant is seen above.

[illegible]

nd then the lower, then the higher sails ;
t length the summit of the towering mast
lone is seen : nor less, when from the ship
he longing sailor's eye in hope of shore :
or then, from the top-mast, tho' more remote
han either deck, the shore is first beheld.

LOFFT'S EUDOSIA.

harles. When I stood by the sea-side water did *not* appear to me to be curv-

utor. Perhaps not; but its convexity be discovered upon any still water; as a river, which is extended a mile or in length, for you might see a very l boat at that distance while standing ght; if then you stoop down so as to your eye near the water, you will find urface of it rising in such a manner as over the boat, and intercept its view pletely. Another proof of the globular e of the earth is, that it is necessary those who are employed in cutting ls, to make a certain allowance for the exity; since the true level is not a ght line, but a curve which falls below *ht inches every* mile.

s 2

James. What are the poles, sir?

Tutor. In the artificial globe (Plate V. Fig. 4.) there is an axis N S about which it turns; now the two extremities or ends of this axis N and S are called the poles.

> The globe terrestrial, with its slanting poles,
> And all its pond'rous load, unwearied rolls.
>
> BLACKMORE.

Charles. Is there any axis belonging to the earth?

Tutor. No; but, as we shall to-morrow show, the earth turns round once in every 24 hours, so astronomers imagine an axis upon which it revolves as upon a centre, the extremities of which imaginary axis are the poles of the earth, of these N the north pole points at all times exactly to *p*, (Fig. 1.) the north pole of the heavens which we have already described, and which is, as you recollect, within two degrees of the polar star.

James. And how do you define the *equator*?

me port from whence he set out. The
me with respect to Great Britain, was
ne by our own countrymen Sir Francis
rake, Lord Anson, Captain Cook, and
any others.

Charles. Is then the common terrestrial obe a just representation of the earth?

Tutor. It is with this small difference*, at the artificial globe is a perfect sphere, hereas the earth is a spheroid, that is, in e shape of an orange, the diameter from *le to pole*, being about 37 miles shorter an that at the *equator*.

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* What the earth loses of its sphericity, by mounins and vallies, is very inconsiderable: the highest ountain bearing so little proportion to its bulk, as arcely to be equivalent to the minutest protuberance the surface of an orange:

These inequalities to us seem great;
But to an eye that comprehends the whole,
The tumour which to us so monstrous seems,
Is as a grain of sparkling sand that clings
To the smooth surface of a sphere of glass;
Or as a fly upon the convex dome
Of a sublime, stupendous edifice.

LOFFT.

proofs adduced for the globular form of the earth, there are others equally conclusive, which will be better understood a few days hence.

CONVERSATION XXVIII.

Of the diurnal Motion of the Earth.

TUTOR. Well, gentlemen, are you satisfied that the earth on which you tread is a globular body and not a mere extended plane?

Charles. Admitting the facts which you mentioned yesterday, viz. that the top-mast of a ship at sea is always visible before the body of the vessel comes into sight;—that navigators have repeatedly, by keeping the same direction, sailed round the world;—and that persons employed in digging canals, can only execute their work with effect, by allowing for the supposed globular shape of the earth, it is evident the earth cannot be a *mere extended* plane.

James. But all these facts can be counted for, upon the supposition that earth is a globe, and therefore you concl it is a globe: this was, I believe, the na of the proof?

Tutor. It was; let us now advance step farther, and show you that this g turns on an imaginary axis every tw four hours; and thereby causes the su sion of day and night:

And earth self-balanc'd on her centre hung.

PAR. I

James. I shall wonder if you ar to afford such satisfactory evidence daily motion of the earth, as of its gl form.

Tutor. I trust, nevertheless, th arguments on this subject will be suf ly convincing, and that before we pa will admit, that the apparent motion sun and stars is occasioned by the motion of the earth.

Charles. I shall be glad to hear h can be proved; for if in the morning, at the sun when rising, it appears in th

at noon it has travelled to the south, and in the evening I see it set in the western part of the heavens.

James. Yes, and we observed the same last night (March the first) with respect to *Arcturus*, for about eight o'clock it had just risen in the north-east part of the heavens, and when we went to bed two hours after, it had ascended a good height in the heavens, evidently travelling towards the west.

Tutor. It cannot be denied that the heavenly bodies appear to rise in the east and set in the west; but the *appearance* will be the *same* to us, whether those bodies revolve about the earth while that stands still, or they stand still while the earth turns on its axis the contrary way.

Charles. Will you explain this, Sir?

Tutor. Suppose G R C B (Plate VI. Fig. 5.) to represent the earth, T the centre on which it turns from west to east, according to the order of the letters G R C B. If a spectator on the surface of the earth at R, see a star at H, it will appear to him to have just risen; if now the earth be supposed to

turn on its axis a fourth part of a revolution, the spectator will be carried from E to C, and the star will be just over his head; when another fourth part of the revolution is completed, the spectator will be at B, and to him the star at H will be setting, and will not be visible again till he arrive, by the rotation of the earth, at the station R.

Charles. To the spectator, then, at R the appearance would be the same whether he turned with the earth into the situation B, or the star at H had described, in a contrary direction, the space H Z O in the same time.

Tutor. It certainly would.

James. But if the earth really turned on its axis, should we not perceive the motion.

Tutor. The earth in its diurnal rotation being subject to no impediments by resisting obstacles, its motion cannot affect the senses. In the same way ships on a smooth sea are frequently turned entirely round by the tide, without the knowledge of those persons who happen to be busy in the cabin or between the decks.

Charles. That is, because they pay no attention to any other object but the vessel in which they are. Every part of the ship moves with themselves.

James. But if while the ship is turning, without their knowledge, they happen to be looking at fixed distant objects, what will be the appearance?

Tutor. To them, the objects which are at rest will appear to be turning round the contrary way. In the same manner we are deceived in the motion of the earth round its axis; for if we attend to nothing but what is connected with the earth, we cannot perceive a motion of which we partake ourselves, and if we fix our eyes on the heavenly bodies, the motion of the earth being so easy, they will appear to be turning in a direction contrary to the real motion of the earth.

Charles. I have sometimes seen a sky-lark hovering and singing over a particular field for several minutes together; now if the earth is continually in motion while the

bird remains in the same part of the air, why do we not see the field, over which he first ascended, pass from under him?

Tutor. Because the atmosphere, in which the lark is suspended, is connected with the earth, partakes of its motion, and carries the lark along with it; and therefore, independently of the motion given to the bird by the exertion of its wings, it has another in common with the earth, yourself, and all things on it, and being common to us all, we have no methods of ascertaining the fact by means of the senses. The rotation of the earth on its axis, the smoothness of its motion, and its effect on the atmosphere, are described by Milton in three lines:

——That spinning sleeps
On her soft axle as she paces even,
And bears us swift with the smooth air along.

James. Though the motion of a ship cannot be observed without objects at rest to compare with it, yet I cannot help thinking if the earth moved, we should be

able to discover it by means of the stars if they are fixed.

Tutor. Do you not remember once sailing very swiftly on the river, when you told me that you thought all the trees, houses, &c. on its banks were in motion?

James. I now recollect it well, and I had some difficulty in persuading myself that it was not so.

Charles. This brings to my mind a still stronger deception of this sort: when travelling with great speed in a post-chaise, I suddenly waked from a sleep in a smooth but narrow road, and I could scarcely help thinking, for several minutes, but that the trees and hedges were running away from us, and not we from them.

Tutor. I will mention another curious instance of this kind; if you ever happen to travel pretty swiftly in a carriage by the side of a field ploughed into long narrow ridges, and perpendicular to the road, you will think that all the ridges are turning round in a direction contrary to that of the carriage. These facts may satisfy you

that the appearances will be precis
same to us, whether the earth turn
axis from west to east, or the sun a
move from east to west.

James. They will: but which is t
natural conclusion?

Tutor. This you shall determ
yourself. If the earth (Pl. v. Fig. 4.)
its axis in 24 hours, at what rate v
part of the equator A B move?

Charles. To determine this w
find the measure of its circumferen
then dividing this by 24, we shall
number of miles passed through in
Tutor. Just so: now call the semi
ter of the earth 4000 miles, which i
more than the true measure.

James. Multiplying this by si

---

* If the reader would be accurate in his c
he must take the mean radius of the ear
miles, and this multiplied by 6,28318 will g
miles for the circumference. Through the
of this work, the decimals in multiplication a
in order that the mind may not be burdene
It seemed necessary, however, in

give 24,000 miles for the circumference of the earth at the equator, and this divided by 24, gives 1000 miles for the space passed through in an hour.

Tutor. You are right. The sun, I have already told you, is 95 millions of miles distant from the earth; tell me therefore, Charles, at what rate that body must travel to go round the earth in 24 hours?

Charles. I will; 95 millions multiplied by six will give 570 millions of miles for the length of his circuit, this divided by 24 gives nearly 24 millions of miles for the space he must travel in an hour, to go round the earth in a day.

Tutor. Which now is the more probable conclusion, either that the earth should have a diurnal motion on its axis of 1000 miles in an hour, or that the sun, which is a million of times larger than the earth, should

---

to give the true semi-diameter of the earth, and the number (accurate to five places of decimals), by which, if the *radius* of any circle be multiplied, the circumference is obtained.

travel 24 millions of miles in the same time?

James. It is certainly more rational to conclude that the earth turns on its axis, the effect of which you told us was the alternate succession of day and night.

Tutor. I did; and on this and some other topics we will enlarge to-morrow.

CONVERSATION XXIX.

Of Day and Night.

AMES. You are now, Sir, to apply rotation of the earth about its axis to succession of day and night.

utor. I will; and for this purpose, sup- G R C B (Plate VI. Fig. 5.) to be the h, revolving on its axis, according to order of the letters, that is, from G to R, C, &c. If the sun be fixed in the hea- s at Z, and a line H O be drawn through centre of the earth T, it will represent circle, which when extended to the vens is called the *rational horizon*.

harles. In what does this differ from *sensible horizon?*

utor. The *sensible horizon* is that circle he heavens which bounds the spectator's

view, and which is greater or less, according as he stands higher or lower. For example; an eye placed at *five* feet above the surface of the earth or sea, sees $2\frac{3}{4}$ miles every way: but if it be at 20 feet high, that is 4 times the height, it will see $5\frac{1}{2}$ miles, or twice the distance.*

Charles. Then the *sensible* differs from the *rational* horizon in this, that the *former* is seen from the surface of the earth, and the *latter* is supposed to be viewed from its centre.

Tutor. You are right; and the rising and setting of the sun and stars are always referred to the *rational* horizon.

James. Why so? they appear to rise and set as soon as they get above, or sink below that boundary which separates the visible from the invisible part of the heavens.

Tutor. They do not, however: and the reason is this, that the distance of the sun and fixed stars is so great in comparison of

* See Dr. Ashworth's Trigonometry, Prop. 31. 2d Edition. 1803.

4000 miles (the difference between the surface and centre of the earth,) that it can scarcely be taken into account.

Charles. But 4000 miles seem to me an immense space.

Tutor. Considered separately, they are so, but when compared with 95 millions of miles, the distance of the sun from the earth, they almost vanish as nothing.

James. But do the rising and setting of the moon, which is at the distance of 240 thousand miles only, respect also the rational horizon?

Tutor. Certainly; for 4000 compared with 240 thousand, bear only the proportion of 1 to 60. Now if two spaces were marked out on the earth in different directions, the one 60 and the other 61 yards, should you at once be able to distinguish the greater from the less?

Charles. I think not.

Tutor. Just in the same manner does the distance of the centre from the surface of the *earth vanish* in comparison of its distance *from* the moon.

James. We must not, however, forget the succession of day and night.

Tutor. Well then; if the sun be supposed at Z, it will illuminate by its rays, all that part of the earth that is above the horizon H O: to the inhabitants at G, its western boundary, it will appear just rising; to those situated at R, it will be noon; and to those in the eastern part of the horizon C, it will be setting.

Charles. I see clearly why it should be noon to those who live at R, because the sun is just over their heads, but it is not so evident, why the sun must appear rising and setting to those who are at G and C.

Tutor. You are satisfied that a spectator cannot, from any place, observe more than a semi-circle of the heavens at any one time; now what part of the heavens will the spectator at G observe?

James. He will see the concave hemisphere Z O N.

Tutor. The boundary to his view will be N and Z, will it not?

Charles. Yes; and consequently th

sun at Z, will to him be just coming into sight.

Tutor. Then by the rotation of the earth, the spectator at G will in a few hours come to R, when, to him, it will be noon; and those who live at R, will have descended to C; now what part of the heavens will they see in this situation?

James. The concave hemisphere N H Z, and Z being the boundary of their view one way, the sun will to them be setting.

Tutor. Just so. After which they will be turned away from the sun, and consequently it will be night to them till they come again to G. Thus, by this simple motion of the earth on its axis, every part of it is, by turns, enlightened and warmed by the cheering beams of the sun.

Charles. Does this motion of the earth account also for the apparent motion of the fixed stars?

Tutor. It is owing to the revolution of the earth round its axis, that we imagine the whole starry firmament revolves about the earth in 24 hours.

James. If the heavens appear to turn on an axis, must there not be two points, namely, the extremities of that imaginary axis, which always keep their position?

Tutor. Yes, we must be understood to except the two celestial poles which are opposite to the poles of the earth, consequently each fixed star appears to describe a greater or a less circle round these, according as it is more or less remote from those celestial poles.

Charles. When we turn from that hemisphere in which the sun is placed, we immediately gain sight of the other in which the stars are situated.

Tutor. Every part of the heaven is decorated with these glorious bodies: and

> Night opes the noblest scenes, and sheds an awe,
> Which gives those venerable scenes full weight,
> And deep reception in th' intender'd heart.
> This gorgeous apparatus! This display!
> This ostentation of creative power!
> This theatre! what eye can take it in?
> By what divine enchantment was it rais'd
> For minds of the first magnitude to launch

In endless speculation, and adore?
One sun by day, by night ten thousand shine;
And light us deep into the Deity;
How boundless in magnificence and might!

YOUNG.

James. If every part of the heavens be thus adorned, why do we not see the stars in the day as well as the night?

Tutor. Because in the day time, the sun's rays are so powerful, as to render *those* coming from the fixed stars invisible. But if you ever happen to go down into any very deep mine, or coal-pit, where the rays of the sun cannot reach the eye, and it be a clear day, you may by looking up to the heavens, see the stars at noon as well as in the night.

Charles. If the earth always revolve on its axis in 24 hours, why does the length of the days and nights differ in different seasons of the year?

Tutor. This depends on other causes connected with the earth's *annual* journey round the sun, upon which we will converse the next time we meet.

CONVERSATION XXX.

Of the Annual Motion of the Earth.

TUTOR. Besides the *diurnal* moti of the earth by which the succession of d and night is produced; it has anoth called its *annual* motion, which is the joı ney it performs round the sun in 365 da 5 hours, 48 minutes, and 49 seconds.

Charles. Are the different seasons to accounted for by this motion of the earı

Tutor. Yes, it is the cause of the c ferent lengths of the days and nights, a consequently of the different seasons, v *Spring*, *Summer*, *Autumn* and *Winter:*

It shifts the seasons, months, and days,
The short-liv'd offspring of revolving time;
By turns they die, by turns are born.
Now cheerful Spring the circle leads
And strews with flow'rs the smiling meads;
Gay Summer next, whom russet robes adorn,
And waving fields of yellow corn;
Then Autumn, who with lavish stores the lap of Nature spreads;
Decrepit Winter, laggard in the dance
(Like feeble age opprest with pain,)
A heavy season does maintain,
With driving snows and winds and rain;
Till Spring recruited to advance,
The various year rolls round again.

HUGHES.

James. How is it known that the earth makes this annual journey round the sun?

Tutor. I told you yesterday, that through the shaft of a very deep mine, the stars are visible in the day as well as in the night; they are also visible in the day time, by means of a telescope properly fitted up for the purpose; by this method, the sun and stars are visible at the same time. Now if the sun be seen in a line with a fixed star,

to-day at any particular hour, it will
few weeks, by the motion of the
be found considerably to the east of
and if the observations be continued th
the year, we shall be able to trac
round the heavens to the same fixe
from which we set out; conseq
the sun must have made a journey
the earth in that time, or the earth
him.

Charles. And the sun being a r
of times larger than the earth, you w
that it is more natural, that the s
body should go round the larger, th
reverse.

Tutor. That is a proper argumen
it may be stated in a much stronger m
The sun and earth mutually attra
another, and since they are in equ
by this attraction, you know, their mo
must be equal,* therefore the earth

* See Conversation XIV. p. 100.

e smaller body, must make out by its otion what it wants in the quantity of its atter, and, of course, it must be that which rforms the journey.

James. But if you refer to the princi-e of the lever, to explain the mutual at-action of the sun and earth, it is evident at both bodies must turn round some int as a common centre.

Tutor. They do; and that is the com-on centre of gravity of the two bodies. ow this point between the earth and sun within the surface of the latter body.

Charles. I understand how this is; be-use the centre of gravity between any o bodies, must be as much nearer to the ntre of the larger body than the smaller, the former contains a greater quantity of tter than the latter.

Tutor. You are right: but you will not nclude that, because the sun is a million times larger than the earth, therefore, contains a quantity of matter, a million times greater than that contained in the th.

[illegible] greater than that of the s[illegible]
[illegible] quantity of matter in the [illegible]
[illegible] three hundred [illegible]
[illegible] than that which is [illegible]

[illegible] the moment [illegible]
[illegible] the [illegible]
[illegible] and [illegible]
[illegible] greater than [illegible]

[illegible] effect [illegible]
[illegible] the sun [illegible]
[illegible] in the [illegible]
[illegible] the centre of [illegible]
[illegible]
[illegible] the latter [illegible]

y, that it must of necessity, be the earth ich revolves about the sun, and not the ı round the earth.

Tutor. Your inference is just. To suppe that the sun moves round the earth, is absurd as to maintain, that a mill-stone ıld be made to move round a pebble.

CONVERSATION XXXI.

Of the Seasons.

TUTOR. I will now show you how different seasons are produced by the ann motion of the earth.

James. Upon what do they depe Sir ?

Tutor. The variety of the seasons pends (1,) upon the length of the days : nights ; and (2,) upon the position of earth with respect to the sun.

Charles. But if the earth turn rou its imaginary axis every 24 hours ou it not to enjoy equal days and nights all year ?

Tutor. This would be the case if the axis of the earth N S (Plate VI. Fig. 6.) were perpendicular to a line C E drawn through the centres of the sun and earth; for then as the sun always enlightens one half of the earth by its rays, and as it is day at any given place on the globe, so long as that place continues in the enlightened hemisphere, every part, except the two poles, must, during its rotation on its axis, be one half of its time in the light and the other half in darkness: or, in other words, the days and nights would be equal to all the inhabitants of the earth, excepting to those, if any, who live at the poles.

James. Why do you except the people at the poles?

Tutor. Because the view of the spectator situated at the poles N and S, must be bounded by the line C E, consequently to him the sun would never appear to rise, or set, but would always be in the horizon.

Charles. If the earth were thus situated, would the rays of the sun always fall vertically to the same part of it?

Tutor. They would: and that part would be E Q the equator; and, as we shall presently show, the heat excited by the sun being greater or less in proportion as its rays come more or less perpendicularly upon any body, the parts of the earth about the equator would be scorched up, while those beyond forty or fifty degrees on each side of that line and the poles, would be desolated by an unceasing winter:

——————Some say the sun
Was bid turn reins from th' *equinoctial* road
Up to the *Tropic Crab;* thence down amain
By *Leo*, and the *Virgin*, and the *Scales*
As deep as *Capricorn*, to bring in change
Of seasons to each clime: else had the spring
Perpetual smil'd on earth with vernant flowers,
Equal in days and nights, except to those
Beyond the *polar* circles: to them day
Had unbenighted shone, while the low sun
To recompense his distance, in their sight
Had rounded still th' horizon.

PAR. LOST, Book x. l. 672.

James. In what manner is this prevented?

Tutor. By the axis of the earth N S (Plate VI. Fig. 7.) being inclined or bent about twenty-three degrees and a half out of the perpendicular as it is described by Milton:

> ———He bid his angels turn askance
> The poles of earth twice ten degrees and more
> From the sun's axis.

In this case you observe, that all the parallel circles, except the equator, are divided into two unequal parts having a greater or less portion of their circumferences in the enlightened, than in the dark hemisphere, according to their situation with respect to N the north, or S the south pole.

Charles. At what season of the year is the earth represented in this figure?

Tutor. At our summer season: for you observe that the parallel circles in the northern hemisphere have their greater

parts enlightened and their smaller parts i the dark. If D L represent that circle latitude on the globe in which Great Br tain is situated, it is evident that abo two thirds of it is in the light and only o third in darkness.

You will remember that *parallels of lat tude* are supposed circles on the surface the earth, and are shown by real circles its representative the terrestrial globe, draw parallel to the equator.

James. Is that the reason why ou days towards the middle of June are six teen hours long, and the nights but eig hours?

Tutor. It is: and if you look to th parallel next beyond that marked D L, yo will see a still greater disproportion b tween the day and night, and the parall more north than this is entirely in the ligh

Charles. Is it then all day there?

Tutor. To the whole space between th and the pole it is continual day for som time, the duration of which is in propo tion to its vicinity to the pole; and at th

pole there is a permanent day-light for six months together.

James. And during that time it must, I suppose, be night to the people who live at the south-pole?

Tutor. Yes, the figure shows that the south-pole is in darkness; and you may observe, that to the inhabitants living in equal parallels of latitude, the one north, and the other south, the length of the days to the one will be always equal to the length of the nights to the other.

Charles. What then shall we say to those who live at the equator, and consequently who have no latitude?

Tutor. To them the days and nights are *always* equal, and of course twelve hours each in length, and this is also evident from the figure, for in every position of the globe one half of the equator is in the light and the other half in darkness.

James. If, then, the length of the days is the cause of the different seasons, there can be no variety in this respect, to those who live at the equator.

Tutor. You seem to forget that the change in the seasons depends upon the position of the earth with respect to the sun, that is, upon the *perpendicularity* with which the rays of light fall upon any particular part of the earth; as well as upon the length of days.

Charles. Does this make any material difference with regard to the heat of the sun?

Tutor. It does: let A B (Plate VI. Fig. 8.) represent a portion of the earth's surface, on which the sun's rays fall perpendicularly; let B C represent an equal portion on which they fall obliquely or aslant. It is manifest that B C, though it be equal to A B, receives but half the light and heat that A B does. Moreover, by the sun's rays coming more perpendicularly, they come with greater force, as well as in greater numbers, on the same place.

CONVERSATION XXXII.

Of the Seasons.

TUTOR. Let us now take a view of the earth in its annual course round the sun, considering its axis as inclined 23½ degrees to a line perpendicular to its orbit, and keeping, through its whole journey, a direction parallel to itself; and you will find, that according as the earth is in different parts of its orbit, the rays of the sun are presented perpendicularly to the equator, and to every point of the globe, within 23½ degrees of it both north and south.

This figure (Plate VI. Fig. 9.) represents the earth in four different parts of its orbit, or as it is situated with respect to the sun *in the months of* March, June, September, *and December*.

the nights short; therefore the earth and air are heated by the sun in the day, more than they are cooled in the night.

James. Why have we not, then, the greatest heat at the time when the days are longest?

Tutor. The hottest season of the year is certainly a month or two after this, which may be thus accounted for. A body once heated does not grow cold again instantaneously, but gradually; now, as long as more heat comes from the sun in the day, than is lost in the night, the heat of the earth and air will be daily increasing, and this must evidently be the case for some weeks after the longest day, both on account of the number of rays which fall on a given space, and also from the perpendicular direction of those rays.

James. Will you now explain to us in what manner the seasons are produced?

Tutor. By referring to the figure (Plate VI. Fig. 9.) you will observe, that in the month of June, the north-pole of the earth inclines towards the sun, and consequently

brings all the northern parts of the globe more into light, than at any other time in the year.

Charles. Then to the people in those parts it is summer.

Tutor. It is: but in December, when the earth is in the opposite part of its orbit, the north-pole declines from the sun, which occasions the northern places to be more in the dark than in the light; and the reverse at the southern places.

James. Is it then summer to the inhabitants of the southern hemisphere?

Tutor. Yes, it is; and winter to us. In the months of March and September, the axis of the earth does not incline to, nor decline from, the sun, but is perpendicular to a line drawn from its centre. And then the poles are in the boundary of light and darkness, and the sun being directly vertical to, or over the equator, makes equal day and night at all places. Now trace the annual motion of the earth in its orbit for yourself, as it is represented in the figure.

Charles. I will, Sir: about the 20th of March the earth is in Libra, and consequently to its inhabitants the sun will appear in Aries, and be vertical to the equator.

Tutor. And then the equator and all its parallels, are equally divided between the light and dark.

Charles. Consequently the days and nights are equal all over the world. As the earth pursues its journey from March to June, its northern hemisphere comes more into light, and on the 21st of that month, the sun is vertical to the tropic of Cancer.

Tutor. And you then observe that all the circles parallel to the equator are unequally divided; those in the northern half have their greater parts in the light, and those in the southern half have their larger parts in darkness.

Charles. Yes; and of course it is summer to the inhabitants of the northern hemisphere, and winter to the southern.

I now trace it to September, when I find the sun vertical again to the equator, and of course, the days and nights are again equal.

And following the earth in its journey to December, or when it has arrived at Cancer, the sun appears in Capricorn; and is is vertical to that part of the earth called the tropic of Capricorn, and now the southern pole is enlightened, and all the circles on that hemisphere have their larger parts in light, and, of course, it is summer to those parts, and winter to us in the northern hemisphere.

Tutor. Can you, James, now tell me why the days lengthen and shorten from the equator to the polar circles every year?

James. I will try to explain myself on the subject. Because the sun in March is vertical to the equator, and from that time to the 21st of June it becomes vertical successively to all other parts of the earth, between the equator and the tropic of Cancer, and in proportion as it becomes vertical to the more northern parts of the earth, it declines from the southern, and, consequently, to the former the days lengthen, and to the latter they shorten. From June to September the sun is again vertical successively to

all the same parts of the earth, but in
verse order.

Charles. Since it is summer to all
parts of the earth, where the sun is ve
and we find that the sun is vertical tw
the year to the equator, and every p
the globe beween the equator and t
there must be also two summers in
to all those places.

Tutor. There are; and in those
near the equator, they have two ha
every year.——But let your brother
his description.

James. From September to Dec
it is successively vertical to all the p
the earth situated between the equat
the tropic of Capricorn, which is al
cause of the lengthening of the days
southern hemisphere, and of their bec
shorter in the northern.

Tutor. Can you, Charles, tell m
there is sometimes no day or night fo
little time together within the polar c

Charles. The sun always shines up
earth 90 degrees every way, and whe

vertical to the tropic of Cancer, which is $23\frac{1}{2}$ degrees north of the equator, he must shine the same number of degrees beyond the pole, or to the polar circle, and while he thus shines, there can be no night to the people within that polar circle; and, of course, to the inhabitants at the southern polar circle, there can be no days at the same time, for as the sun's rays reach but 90 degrees every way, they cannot shine far enough to reach them.

Tutor. Tell me, now, why there is but one day and night in the whole year at the poles?

Charles. For the reason which I have just given, the sun must shine beyond the north-pole all the time he is vertical to those parts of the earth, situated between the equator and the tropic of Cancer, that is, from March the 21st, to September the 20th, during which time there can be no night at the north-pole, nor any day at the south-pole. The reverse of this may be applied to the *southern pole*.

James. *I* understand now, that the

lengthening and shortening of the days, and different seasons, are produced by the annual motion of the earth round the sun; the axis of the earth, in all parts of its orbit, being kept parallel to itself. But if thus parallel to itself, how can it in all positions point to the pole-star in the heavens?

Tutor. Because the diameter of the earth's orbit A C is nothing in comparison of the distance of the earth from the fixed stars. Suppose you draw two parallel lines at the distance of three or four yards from one another, will they not both point to the moon when she is in the horizon?

James. Three or four yards cannot be accounted as any thing, in comparison of 240 thousand miles, the distance of the moon from us.

Tutor. Perhaps three yards bear a much greater proportion to 240 thousand miles, than 190 millions of miles bear to our distance from the polar star.

)NVERSATION XXXIII.

Of the Equation of Time.

ƆR. You are now, I presume, ɜd with the motions peculiar to this which we live?

's. Yes: it has a rotation on its n west to east every 24 hours, by ay and night are produced, and apparent diurnal motion of the from east to west.

:. The other is its annual revolu- an orbit round the sun, likewise st to east, at the distance of about ɔns of miles from the ·sun.

. You understand also, in what

manner this annual motion of the combined with the inclination of its is the cause of the variety of season

We will therefore proceed to inves another curious subject, viz. the equ of time, and to explain to you the diffe between *equal* and *apparent* time.

Charles. Will you tell us what you by the words *equal* and *apparent*, as a to time?

Tutor. *Equal* time is measured clock, that is supposed to go withou variations, and to measure exactly 24 from noon to noon. And *apparent* t measured by the *apparent* motion c sun in the heavens, or by a good sun

Charles. And what do you mean by the *equation of time?*

Tutor. It is the adjustment of th ference of time, as shown by a well-lated clock and a true sun-dial.

James. Upon what does this diffe depend?

Tutor. It depends *first*, upon the *nation* of the earth's axis. And se

upon the elliptic form of the earth's orbit; for, as we have already seen, the earth's orbit being an ellipse, its motion is quicker when it is in *perihelion*, or nearest to the sun; and slower when it is in *aphelion*, or farthest from the sun.

Charles. But I do not yet comprehend what the rotation of the earth has to do with the going of a clock or watch.

Tutor. The rotation of the earth is the most equable and uniform motion in nature, and is completed in 23 hours, 56 minutes, and 4 seconds; this space of time is called a *sidereal* day, because any meridian on the earth will revolve from a fixed star, to that star again in this time. But a *solar* or natural day, which our clocks are intended to measure, is the time which any meridian on the earth will take in revolving from the sun to the sun again, which is about 24 hours, sometimes a little more, but generally less.

James. What occasions this difference betwen the solar and sidereal day?

Tutor. The distance of the fixed stars

is so great, that the diameter of
orbit, though 190 millions of n
compared with it, is but a
therefore any meridian on the
revolve from a fixed star to that
in exactly the same time, as if
had only a diurnal motion, and
always in the same part of its or
with respect to the sun, as the e
vances almost a degree eastward i
bit, in the same time that it turn
ward round its axis, it must mak
than a complete rotation before it ca
into the same position with the su
it had the day before. In the sam
as when both the hands of a wa
clock set off together as twelve o
the minute-hand must travel mor
a whole circle before it will overta
hour-hand, that is, before they will
the same relative position again. Th
sidereal days are shorter than the sol
by about four minutes, as is eviden
observation :

Watch with nice eye the earth's diurnal way
Marking her *solar* and *sidereal* day;
Her slow nutation, and her varying clime,
And trace with mimic art the march of time.

BOTANIC GARDEN.

Charles. Still I do not understand the reason why the clocks and dials do not agree.

Tutor. A good clock is intended to measure that equable and uniform time which the rotation of the earth on its axis exhibits. Whereas the dial measures time by the *apparent* motion of the sun, which, as we have explained, is subject to variation. Or thus: though the earth's motion on its axis be perfectly uniform, and consequently the rotation of the *equator*, the plane of which is perpendicular to the axis, or of any other circle parallel to it, be likewise equable, yet we measure the length of the natural day by means of the sun, whose *apparent* annual motion is not in the equator, or any of its parallels, but in the *ecliptic, which* is oblique to it.

James. Do you mean by this, that the equator of the earth, in its annual journey, is not always directed towards the centre of the sun?

Tutor. I do: twice only in the year, a line drawn from the centre of the sun to that of the earth passes through those points where the equator and ecliptic cross one another; at all other times, it passes through some other part of that oblique circle, which is represented on the globe by the ecliptic line. Now when it passes through the equator or the tropics, which are circles parallel to the equator, the sun and the clocks go together as far as regards this cause, but at other times they differ, because *equal* portions of the ecliptic pass over the meridian in *unequal* parts of time on account of its obliquity.

Charles. Can you explain this by a figure?

Tutor. It is easily shown by the globe which this figure ♈ N ♎ S (Plate VI. Fig. 10.) may represent; ♈ ♎ will be the equator, ♈ ♋ ♎ the northern half of the ecliptic, and ♈ ♑ ♎ the southern half. Make

chalk or pencil marks *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, all round the *equator* and *ecliptic*, at equal distances (suppose 20 degrees) from each other, beginning at Aries. Now by turning the globe on its axis, you will perceive that all the marks in the first quadrant of the *ecliptic*, that is, from Aries to Cancer, come *sooner* to the brazen meridian than their corresponding marks on the *equator*:—those from the beginning of Cancer to Libra come *later*:—those from Libra to Capricorn sooner:—and those from Capricorn to Aries later.

Now time as measused by the sun-dial is represented by the marks on the *ecliptic*; that measured by a good clock, by those on the *equator*.

Charles. Then while the sun is in the first and third quarters, or what is the same thing, while the earth is travelling through the second and fourth quarters, that is, from Cancer to Libra, and from Capricorn to Aries, the sun is faster than the clocks, and while it is travelling the other two quarters it is slower.

Tutor. Just so: because while the earth is travelling through the second and fourth quadrants, equal portions of the ecliptic come *sooner* to their meridian than their corresponding parts of the equator: and during its journey through the first and third quadrants, the equal parts of the ecliptic arrive *later* at the meridian than their corresponding parts of the equator.

James. If I understand what you have been saying, the dial and clocks ought to agree at the equinoxes, that is, on the 20th of March, and the 23d of September, but if I refer to the Ephemeris, I find that on the former day (1809) the clock is 8 minutes before the sun: and on the latter day the clock is almost 8 minutes behind the sun.

Tutor. If this difference between time measured by the dial and clock depended only on the inclination of the earth's axis to the plane of its orbit, the clocks and dial ought to be together at the equinoxes, and also on the 21st of June and the 21st of December, that is, at the summer and winter solstices; because, on those days, the

pparent revolution of the sun is parallel to he equator. But I told you there was an-ther cause why this difference subsisted.

Charles. You did: and that was the el-iptic form of the earth's orbit.

Tutor. If the earth's motion in its orbit ere uniform, which it would be if the or-it were circular, then the whole difference etween *equal* time as shown by the clock, nd *apparent* time as shown by the sun, ould arise from the inclination of the arth's axis. But this is not the case, for e earth travels, when it is nearest the sun, at is, in the winter, more than a degree in 4 hours, and when it is farthest from the in, that is, in summer, less than a degree the same time: consequently from this use the natural day would be of the great-st length when the earth was nearest the un, for it must continue turning the longest me after an entire rotation, in order to ring the meridian of any place to the sun gain: and the shortest day would be when he earth moves the slowest in her orbit. Now these inequalities, combined with

those arising from the inclination earth's axis, make up that differenc is shown by the equation table, founc Ephemeris, between good clocks ar sun-dials.

CONVERSATION XXXIV.

Of Leap Year.

James. Before we quit the subject of time, will you give us some account of what is called in our Almanacs Leap-Year?

Tutor. I will. The length of our year is, as you know, measured by the time which the earth takes in performing her journey round the sun, in the same manner as the length of the day is measured by its rotation on its axis. Now, to compute the exact time taken by the earth in its annual journey, was a work of considerable difficulty. Julius Cæsar was the first person who seems to have attained to any accuracy on this subject.

Charles. Do you mean the first roman Emperor, who landed also in Great-Britain?

Tutor. I do. He was not less celebrated as a man of science, than he was renowned as a general: of him it was said,

> Amidst the hurry of tumultuous war,
> The stars, the gods, the heavens were still his care,
> Nor did his skill to fix the rolling year
> Inferior to Eudoxus's art appear.

Julius Cæsar, who was well acquainted with the learning of the Egyptians, fixed the length of the year to be 365 days and six hours, which made it six hours longer than the Egyptian year. Now, in order to allow for the odd six hours in each year, he introduced an additional day every fourth year, which accordingly consists of 366 days, and is called *Leap*-Year, while the other three have only 365 days each. From him it was denominated the *Julian* year.

James. It is also called *Bissextile* in the Almanacs, what does that mean?

Tutor. The Romans inserted the intercalary day between the 23d and 24th of

year 1752, when the error amounted to nearly 11 days, which were taken from the month of September, by calling the 3d of that month the 14th.

Charles. By what means will this accuracy be maintained?

Tutor. The error amounting to one whole day in about 130 years, it is settled by an act of parliament, that the year 1800 and the year 1900, which are, according to the rule just given, Leap-Years, shall be computed as common years, having only 365 days in each: and that every *four* hundredth year afterwards should be common years also. If this method be adhered to, the present mode of reckoning will not vary a single day from true time, in less than 5000 years.

By the same act of parliament, the legal beginning of the year was changed from the 25th of March to the 1st of January. So that the succeeding months of January, February, and March, up to the 24th day, which would, by the Old Style, have been reckoned part of the year 1752, were ac-

[illegible]w the year begins in January
March.

CONVERSATION XXXV.

Of the Moon.

TUTOR. You are now, gentlemen, acquainted with the reasons for the division of time into days and years.

Charles. These divisions have their foundation in nature, the *former* depending upon the rotation of the earth on its axis; the *latter* upon its revolution in an elliptic orbit about the sun as a centre of motion.

James. Is there any natural reason for the division of years into weeks, or of days into hours, minutes, and seconds?

Tutor. These divisions were invented entirely for the convenience of mankind, and are accordingly in different countries.

There is however, another division of time marked out by nature.

Charles. What is that, Sir?

Tutor. The length of the *month*: not indeed that month which consists of four weeks, nor that by which the year is divided into twelve parts. These are both arbitrary. But by a month is meant the time which the moon takes in performing her journey round the earth:

> Then mark'd astronomers with keener eyes
> The moon's refulgent journey through the skies.
>
> DARWIN.

James. How many days does the moon take for this purpose?

Tutor. If you refer to the time in which the moon revolves from one point of the heavens to the same point again, it consists of 27 days, 7 hours, and 43 minutes, this is called the *periodical* month: but if you refer to the time passed from new moon to new moon again, the month consists of 29 days, 12 hours, and 44 minutes, this is called the *synodical* month.

es. Pray explain the reason of this
e.

. It is occasioned by the earth's
notion in its orbit. Let us refer to
h as an example. The two hands
ther at 12 o'clock; now when the
and has made a complete revolu-
they together again?

. No; for the hour-hand is ad-
the twelfth part of its revolution,
order that the other may overtake,
travel five minutes more than the

. And something more, for the
d does not wait at the figure I, till
r comes up: and therefore they
be together till between 5 and 6
after one.

pply this to the earth and moon,
(Plate VII. Fig. 11.) S to be the
he earth in a part of its orbit Q L;
be the position of the moon; if the
d no motion, the moon would move
s orbit E H C into the position E
27 days, 7 hours, 43 minutes; but

while the moon is describing her journey, the earth has passed through nearly a twelfth part of its orbit, which the moon must also describe before the two bodies come again into the same position that they before held with respect to the sun: this takes up so much more time as to make her synodical month equal to 29 days, 12 hours, and 44 minutes: hence the foundation of the division of time into months.

We will now proceed to describe some other particulars relating to the moon, as a body depending like the earth, on the sun for her light and heat.

Charles. Does the moon shine with a borrowed light only?

Tutor. This is certain; for otherwise, if like the sun, she were a luminous body, she wonld always shine with a full orb as the sun does:

> ———Less bright the moon,
> But opposite in level'd west was set,
> His mirror, with full face *borrowing* her light
> From him, for other light she needed none.

r diameter is nearly 2200 miles in gth.

ames. And I remember she is at the ance of 240,000 miles from the earth.

utor. The sun S (Plate VII. Fig. 11.) ays enlightens one half of the moon E, its whole enlightened hemisphere, or a t of it, or none at all, is seen by us ac- ling to her different positions in the or- with respect to the earth, for only those s of the enlightened half of the moon visible at T which are cut off by, and *within* the orbit.

ames. Then when the moon is at E, no of its enlightened side is visible to the h.

utor. You are right: it is then *new* n, or *change*, for it is usual to call it moon the first day it is visible to the h, which is not till the second day after change. And the moon being in a line veen the sun and earth, they are said to *conjunction.*

harles. And at A all the illuminated *sphere is* turned to the earth.

Tutor. This is called *full* moon; and the earth being between the sun and moon, they are said to be in *opposition*. The enlightened parts of the little figures on the outside of the orbit, represent the appearance of the moon as seen by a spectator on the earth.

James. Is the little figure then opposite E wholly dark to show that the moon is invisible at *change?*

Tutor. It is; and when it is at F a smaller part of the illuminated hemisphere is *within* the moon's orbit, and therefore to a spectator on the earth it appears *horned;* at G one half of the enlightened hemisphere is visible, and it is said to be in *quadrature:* at H three-fourths of the enlightened part is visible to the earth, and it is then said to be *gibbous:* and at A the enlightened face of the moon is turned to the earth, and it is said to be *full*. The same may be said of the rest.

The horns of the moon before conjunction or new moon, are turned to the *east:* after conjunction they are turned to the west

How beautifully is the moon described by Milton:

> ————————till the moon,
> Rising in clouded majesty, at length,
> Apparent Queen unveil'd her peerless light,
> And o'er the dark her silver mantle threw.
>
> Book iv. line 606.

Charles. I see the figure is intended to show that the moon's orbit is elliptical: does she also turn upon her axis?

Tutor. She does; and she requires the same time for her diurnal rotation, as she takes in completing her revolution about the earth; and consequently though every part of the moon is successively presented to the sun, yet the same hemisphere is always turned to the earth. This is known by observation with good telescopes.

James. Then the length of a day and night in the moon is equal to more than twenty-nine days and a half of ours.

Tutor. It is so: and therefore as the length of her year, which is measured by *her journey* round the sun, is equal to that

of ours, she can have but about twelve days and one third in a year. Another remarkable circumstance relating to the moon, is that the hemisphere next the earth is never in darkness, for in the position E when it is turned from the sun, it is illuminated by light reflected from the earth, in the same manner as we are enlightened by a full moon. But the other hemisphere of the moon has a fortnight's light and darkness by turns.

Charles. Can the earth, then, be considered as a satellite to the moon?

Tutor. It would, perhaps, be inaccurate to denominate the larger body a satellite to the smaller, but with regard to affording reflected light, the earth is to the moon, what the moon is to the earth, and subject to the same changes of horned, gibbous, full, &c.

Charles. But it must appear much larger than the moon.

Tutor. The earth will appear to the inhabitants of the moon, about 13 times as large as the moon appears to us. When it

new moon to us, it is *full earth* to them, ıd the reverse.

James. Is the moon then inhabited as ell as the earth?

Tutor. Though we cannot demonstrate is fact, yet there are many reasons to in- ıce us to believe it; for the moon is a se- ndary planet of considerable size;—its rface is diversified like that of the earth ith mountains and valleys;—the former ıve been measured by Dr. Herschel, and me of them found to be about a mile in ight. The situation of the moon, with spect to the sun, is much like that of the rth, and by a rotation on her axis, and a nall inclination of that axis to the plane her orbit, she enjoys, though not a con- lerable, yet an agreeable variety of day ıd night and of seasons. To the moon, ır globe appears a capital satellite, under- ing the same changes of illumination as the oon does to the earth. The sun and stars se and set there as they do here, and hea- bodies will fall on the moon as they do the earth. Hence we are led to conclude

been observed there, nor is the exist
a lunar atmosphere certain. Therefo
inhabitants must materially differ fro
who live upon the earth.

CONVERSATION XXXVI.

Of Eclipses.

CHARLES. Will you, Sir, explain to the nature and causes of eclipses?

Tutor. I will, with great pleasure. You ist observe, then, that eclipses depend up- this simple principle, that all opaque or rk bodies when exposed to any light, and refore to the light of the sun, cast a sha- w behind them in an opposite direction.

James. The earth being a body of this id must cast a very large shadow on its e which is opposite to the sun.

Tutor. It does: and an eclipse of the on happens when the earth T (Plate VII. g. 12.) passes between the sun S and the

moon M, and it is occasioned by the earth' shadow being cast on the moon.

Charles. When does this happen?

Tutor. It is only when the moon is f or in *opposition*, that it comes within t shadow of the earth.

James. Eclipses of the moon, howev do not happen every time it is full: wha the reason of this?

Tutor. Because the orbit of the m does not coincide with the plane of earth's orbit, but one half of it is elev about five degrees and a third above it, the other half is as much below it: therefore, unless the full moon happe or near one of the nodes, that is, in or the points in which the two orbits inte each other, she will pass above, or belov shadow of the earth, in which case ther be no eclipse.

Charles. What is the greatest dis from the node, at which an eclipse o moon can happen?

Tutor. There can be no eclipse, i moon, at the time when she is full, be

than 12 degrees from the node; when she is within that distance, there will be a *partial* or *total* eclipse, according as a part, or the whole disk or face of the moon falls within the earth's shadow. If the eclipse happen exactly when the moon is full in the node, it is called a central eclipse.

James. I suppose the duration of the eclipse lasts all the time that the moon is passing through the shadow.

Tutor. It does: and you observe that the shadow is considerably wider than the moon's diameter, and therefore an eclipse of the moon lasts sometimes three or four hours. The shadow also you perceive is of a conical shape, and consequently, as the moon's orbit is an ellipse and not a circle, the moon will, at different times, be eclipsed when she is at different distances from the earth.

Charles. And according as the moon is nearer to, or farther from the earth, the eclipse will be of a greater or less duration; for the shadow being conical becomes less and less, as the distance from the body by *which it is cast* is greater.

Tutor. It is by knowing exactly distance the moon is from the earth, course the wedth of the earth's sh that distance, that all eclipses are ca with the greatest accuracy, for man before they happen. Now, it is fou in all eclipses, the shadow of the e conical, which is a demonstration, body by which it is projected is of a cal form, for no other sort of figure in *all positions*, cast a conical This is mentioned as another proof, earth is a spherical body.

James. It seems to me to prove thing, viz. that the sun must be body than the earth.

Tutor. Your conclusion is just, fo two bodies were equal to one anothe VII. Fig. 13.) the shadow would b drical: and if the earth were the la dy, (Plate VII. Fig. 14.) its shadow be of the figure of a cone, which h its vertex, and the farther it were e the larger would it become. In eith the shadow would run out to a

, and accordingly must sometimes in-
in it the other planets, and eclipse
which is contrary to fact. Therefore,
the earth is neither larger than, nor
to the sun, it must be the lesser body.
vill now proceed to the eclipses of the

arles. How are these occasioned?

tor. An eclipse of the sun happens
the moon M, passing between the sun
l the earth T (Plate VII. Fig. 15.) in-
pts the sun's light.

mes. The sun then can be eclipsed
at the new moon.

tor. Certainly; for it is only when the
is in *conjunction* that it can pass di-
y between the sun and earth.

arles. Is it only when the moon at her
inction, is near one of its nodes, that
can be an eclipse of the sun?

tor. An eclipse of the sun depends
this circumstance: for unless the moon
, or near one of its nodes, she cannot
ar in the same plane with the sun, or
to pass over his disk. In every other

part of the orbit she will appear above or below the sun. If the moon be *in* one of the nodes she will, in most cases, cover the whole disk of the sun, and produce a *total* eclipse; if she be any where within about 16 degrees of a node, a *partical* eclipse will be produced.

The sun's diameter is supposed to be divided into 12 equal parts, called *digits*, and in every partial eclipse, as many of these parts of the sun's diameter as the moon covers, so many digits are said to be eclipsed.

James. I have heard of *annular* eclipses, what are they, Sir?

Tutor. When a ring of light appears round the edge of the moon during an eclipse of the sun, it is said to be annular, from the Latin word *annulus* a *ring:* these kind of eclipses are occasioned by the moon being at her greatest distance from the earth at the time of an eclipse, because in that situation the vertex or tip of the cone of the moon's shadow does not reach the surface of the earth.

Charles. How long can an eclipse of the un last?

Tutor. A total eclipse of the sun is a very urious and uncommon spectacle; and total larkness cannot last more than three or four ninutes. Of one that was observed in Porugal, 150 years ago, it is said that the larkness was greater than that of the night; —that stars of the first magnitude made heir appearance;—and that the birds were o terified that they fell to the ground.

James. Was this visible only at Portugal?

Tutor. It must have been seen at other places, though we have no account of it. The moon, however, being a body much smaller than the earth, and having also a a conical shadow, can with that shadow only cover a small part of the earth; whereas an eclipse of the moon may be seen by all those that are on that hemisphere which is turned towards it. (See Plate VII. Fig. 15 and 12.)

You will also observe, that an eclipse of the sun may be total to the inhabitants near *the middle* of the earth's disk, and annular o *those in places* near the edges of the disk.

for in the former case the moon's shadow will reach the earth, and in the latter, on account of the earth's spericity, it will not.

Charles. Have not eclipses been esteemed as omens presaging some direful calamity?

Tutor. Till the causes of these appearances were discovered, they were generally beheld with terror by the inhabitants of the world, which fact is beautifully alluded to by Milton in the 1st book of Paradise Lost, line 594:

————As when the sun, new risen,
Looks through the horizontal misty air
Shorn of his beams, or from behind the moon,
In dim eclipse, disastrous twilight sheds
On half the nations, and with fear of change
Perplexes monarchs.

CONVERSATION XXXVII.

Of the Tides.

TUTOR. We will proceed to the consideration of the *ides*, or the flowing and ebbing of the ocean.

James. Is this subject connected with astronomy?

Tutor. It it, inasmuch as the tides are occasioned by the attraction of the sun and moon upon the waters, but more particularly by that of the latter. You will readily receive that the tides are dependent upon some known and determinate laws, because, if you turn to the Ephemeris, or indeed to almost any almanac, you will see that the *exact time of high* water at London-bridge *for every day in the year* is set down.

Charles. I have frequently wonder how this could be known with such a degr of accuracy: indeed there is not a waterm that plies at the stairs, but can readily t when it will be high water.

Tutor. The generality of the waterm are probably as ignorant as yourself of t cause by which the waters flow and ebb, b by experience they know that the time high water differs on each day about thr quarters of an hour, or a little more or le and therefore if it be high water to-day six o'clock, they will, at a guess, tell yo that to-morrow the tide will not be up til quarter before seven.

James. Will you explain the causes?

Tutor. I will indeavour to do this in easy and concise manner, without fatigui your memory with a great variety of pa ticulars:

> The ebbs of tides, and their mysterious flow,
> We, as art's elements, shall understand.
>
> DRYDEN

You must bear in your mind then, t re occasioned by the attractio

moon, and a tide is accordingly produced: but when, by the earth's rotation, A comes, 12 hours afterwards, into the position L, another tide is occasioned by the receding of the waters there from the centre.

James. You have told us that the tides are produced in those parts of the earth to which the moon is vertical, but this effect is not confined to those parts.

Tutor. It is not, but there the attraction of the moon has the greatest effect; in all other parts her force is weaker, because it acts in a more oblique direction.

Charles. Are there two tides in every 24 hours?

Tutor. If the moon were stationary this would be the case; but because that body is also proceeding every day about 13 degrees from west to east in her orbit, the earth must make more than one revolution on its axis before the same meridian is in conjunction with the moon, and hence two tides take place in about 24 hours and 50 *minutes.*

James. But I remember when we were

at the sea, that the tides rose higher at some seasons than at others: how do you account for this?

Tutor. The moon goes round the earth in an elliptic orbit, and therefore she approaches nearer to the earth in some parts of her orbit, than in others. When she is nearest, the attraction is the strongest, and consequently it raises the tides most: and when she is farthest from the earth, her attraction is the least, and the tides the lowest.

James. Do they rise to different heights in different places?

Tutor. They do: in the Black-Sea and the Mediterranean the tides are scarcely perceptible. At the mouth of the Indus the water rises and falls full 30 feet. The tides are remarkably high on the coast of Malay, in the Straits of Sunda, in the Red-Sea, along the coast of China, Japan, &c. In general the tides rise highest and strongest in those places that are narrowest.

Charles. You said the sun's attraction occasioned tides as well as that of the moon.

Tutor. It does: but owing to the immense distance of the sun from the earth, it produces but a small effect in comparison of the moon's attraction. Sir Isaac Newton computed, that the force of the moon raised the waters in the great ocean 10 feet, whereas that of the sun raised it only 2 feet. When both the attraction of the sun and moon act in the same direction, that is, at new and full moon, the combined forces of both raise the tide 12 feet. But when the moon is in her quarters, the attraction of one of these bodies raises the water, while that of the other depresses it; and therefore the smaller force of the sun must be subtracted from that of the moon, consequently the tides will be no more than 8 feet. The highest tides are called spring-tides, and the lowest are denominated neap-tides.

James. I understand that in the former case, the height to which the tides are raised, must be calculated by *adding* together the attractions of the sun and moon; and in the latter, it must be estimated by the *difference of these* attractions.

... When the sun
... to the equator
... her least dis-
... then the tides are

... highest tides happen at

... these tides do
... time after, because
... actions do not
... when they are at
... time afterwards:
... is not when
... between two
...—Another
... no considera-
... the earth in
... nearer
... than in March
... therefore all these
... will be found
... happen ... before
... after the autum-

4

CONVERSATION XXXVIII.

Of the Harvest Moon.

TUTOR. From what we said yesterday, you will easily understand the reason why the moon rises about three quarters of an hour later every day than on the one preceding.

Charles. It is owing to the daily progress which the moon is making in her orbit, on which account any meridian on the earth must make more than one complete rotation on its axis, before it comes again into the same situation with respect to the moon that it had before. And you told us that this occasioned a difference of about 50 *minutes.*

Tutor. At the equator this is genera

the difference of time between the rising of the moon on one day and the preceding. But in places of considerable latitude, as that in which we live, their is a remarkable difference about the time of harvest, who at the season of full moon she rises for several nights together only about 20 minutes later on the one day than on that immediately preceding. By thus succeeding the sun before the twilight is ended, the moon prolongs the light to the great benefit of those who are engaged in gathering in the fruits of the earth; and hence the full moon at this season is called the harvest moon. It is believed that this was observed by persons engaged in agriculture, at a much earlier period than it was noticed by astronomers; the former ascribed it to the goodness of the Deity, not doubting but that he had so ordered it on purpose for their advantage.

James. But the people at the equator do not enjoy this benefit.

Tutor. Nor is it necessary that they should, for in those parts of the earth, the seasons vary but little, and the weather

changes but seldom, and at stated times; to them, then, moon-light is not wanting for gathering the fruits of the earth.

Charles. Can you explain how it happens, that the moon at this season of the year rises one day after another with so small a difference of time?

Tutor. With the assistance of a globe I could at once clear the mater up. But I will endeavour to give you a general idea of the subject without that instrument. That the moon loses more time in her risings when she is in one part of her orbit, and less in another, is occasioned by the moon's orbit lying some times more oblique to the horizon than at others.

James But the moon's path is not marked on the globe.

Tutor. It is not; you may, however, consider it, without much error, as coinciding with the ecliptic. And in the latitude of London, as much of the ecliptic rises about *Pisces* and *Aries* in two hours as the moon goes through in six days; therefore while the moon is in these signs she differs

but two hours in rising for six days together; that is one day with another, about 20 minutes later every day than on the preceding.

> There is a time well known to husbandmen,
> In which the moon for many nights, in aid
> Of there autumnal labours, cheers the dusk
> With her full lustre, soon as Phœbus hides
> Beneath the horizon his propitious ray:
> For as the angle of the line which bounds
> The moon's career from the Equator, flows
> Greater or less, the orb of Cynthia shines
> With less or more of difference in rise;
> In *Aries* least this angle: thence the moon
> Rises with smallest variance of times,
> When in this sign she dwells; and most protracts
> Her sojourning in our enlighten'd skies.
>
> LOFFT.

Charles. Is the moon in those signs at the time of harvest?

Tutor. In August and September you know that the sun appears in Virgo and Libra, and of course when the moon is *full*, she must be in the opposite signs, viz. *Pisces* and *Aries*.

James. Are there then two full moons that afford us this advantage?

Tutor. There are, the one when the sun is in Virgo, which is called the *harvest moon*; the other when the sun is in Libra, and which being less advantageous, is called the *hunter's* moon. You ought to be told that when the moon is in Virgo and Libra, then she rises with the greatest difference of time, viz. an hour and a quarter later every day than the former.

Charles. Will you explain, Sir, how it is that the people at the equator have no harvest moon?

Tutor. At the equator, the north and south poles lie in the horizon, and therefore the ecliptic makes the same the same angle southward with the horizen when Aries rises, as it does northward when Libra rises; but as the harvest moon depends upon the different angles, at which different parts of the ecliptic rises, it is evident there can be no harvest moon at the equator.

The farther any place is from the equator, if it be not beyond the polar circles, the angle which the ecliptic makes with the horizon, when Pisces and Aries rise, gradually

diminishes, and therefore when the mo in these signs she rises with a nearly portionable difference later every day on the former, and this is more remark about the time of full moon.

James. Why have you excepted space on the globe beyond the polar ci

Tutor. At the polar circles, when sun touches the summer tropic, he cont 24 hours above the horizon; and 24 h below it when he touches the winter tr For the same reason the full moon ne rises in the summer, when she is not ed; nor sets in the winter when her pre is so necessary. These are the only tw moons which happen about the tropics all the others rise and set. In summe full moons are low, and their stay abov horizon short: in winter they are high stay long above the horizon. A wond display this of the divine wisdom and ness, in apportioning the quantity of suitable to the various necessities of th habitants of the earth, according to different situations.

les. At the poles, the matter is, I sup-
ill different.

r. There one half of the ecliptic
ts, and the other half never rises;
ently the sun continues one half year
e horizon, and the other half below it.
l moon being always opposite to the
never be seen to the inhabitants of
es, while the sun is above the hori-
it all the time that the sun is below
zon, the full moons never set. Con-
ly to them the full moon is never vi-
he summer; and in their winter they
r always before and after the full,
for 14 of our days and nights with-
rmission. And when the sun is de-
the lowest under the horizon, then
n ascends with her highest altitude.

s. This indeed exhibits in a high
the attention of Providence to all
tures. But if I understand you, the
nts of the poles have in their winter
ght's light and darkness by turns.

r. This would be the case for the
ix months that the sun is below the

horizon; if there were no refraction;* a
no subsitute for the light of the moon. B
by the atmosphere's refracting the sun's ra
he becomes visible a fortnight sooner, a
continues a fortnight longer in sight tha
would otherwise do were there no s
property belonging to the atmosphere. A
in those parts of the winter, when it wo
be absolutely dark in the absence of
moon, the brilliancy of the *Aurora Bore*
is probably so great as to afford a very c
fortable degree of light. Mr. Hearne in
travels near the polar circle, has this
mark in his journal; "December 24.
days were so short, that the sun only to
circuit of a few points of the compass a
the horizon, and did not at its greatest
tude rise half way up the trees. The
liancy of the Aurora Borealis, however,
of the stars, even without the assistanc
the moon, made amends for this deficie

* The subject of refraction will be very particu
explained when we come to Optics.

r it was frequently so light all night, that could see to read a small print."

These advantages are poetically described y our Thomson:

By dancing meteors then, that ceaseless shake
A waving blaze refracted o'er the heavens,
And vivid moons, and stars that keener play
With double lustre from the glossy waste;
Ev'n in the depth of Polar Night, they find
A wond'rous day: enough to light the chase,
Or guide their daring steps to Finland-fairs.

Winter, l. 859.

s his annual journey round the sun in
orbit *a;* Venus in *b*, and the earth,
er from that luminary than either of
, makes its circuit in *t*.

mes. How is this known?

tor. By observation; for by atten-
watching the progress of these bo-
it is found that they are continually
ging their places among the fixed stars,
hat they are never seen in opposition
e sun, that is, they are never seen in
western side of the heavens in the
ing when he appears in the east; nor
e eastern part of the heavens in the
ng when the sun appears in the west.

arles. Then they may be considered
endants upon the sun?

tor. They may: Mercury is never
from the earth at a greater distance
the sun, that about twenty-eight de-
, or about as far as the moon appears
from the sun on the second day after
hange; hence it is that we so seldom
him; and when we do, it is for so
a time, and always in twilight, that

sufficient observations have not been made to ascertain whether he has a diurnal motion on his axis.

James. Would you then conclude that he has such a motion?

Tutor. I think we ought; because it is known to exist in all those planets upon which observations of sufficient extent have been made, and therefore we may surely infer, without much chance of error, that it belongs also to Mercury, and the Herschel, the former from its vicinity to the sun, and the latter from its great distance from that body, having at present eluded the investigation of the most indefatigable astronomers.

Charles. At what distance is Mercury from the sun?

Tutor. He revolves round that body at about thirty-seven millions of miles distance, in eighty-eight days nearly; and therefore you can now tell me how many miles he travels in an hour.

James. I can; for supposing his orbit circular, I must multiply the 37 millions

y 6,* which will give 222 millions of miles for the length of his orbit; this I shall divide by 88, the number of days he takes in performing his journey, and the quotient resulting from this, must be divided by 24, for the number of hours in a day; and by these operations, I find that Mercury travels at the rate of more than 105,000 miles in an hour.

Charles. How large is Mercury?

Tutor. He is the smallest of all the planets. His diameter is something more than 3200 miles in length.

James. His situation being so much nearer to the sun than ours, he must enjoy a considerably greater share of its heat and light.

Tutor. So much so, as would indeed infallibly burn every thing belonging to the earth to atoms, were she similarly situated. The heat of the sun at Mercury, must be seven times greater than our summer heat:

---

* See p. 222.

——————Mercury the first
Near ordering on the day, with speedy wheel
Flies swiftest on, inflaming where he comes,
With *seven-fold* splendour, all the azure road.
MALLET'S EXCURSION.

Charles. And do you imagine that, thus circumstanced, this planet can be inhabited?

Tutor. Not by such beings as we are: you and I could not long exist at the bottom of the sea; yet the sea is the habitation of millions of living creatures; why then may there not be inhabitants in Mercury, fitted for the enjoyment of the situation which that planet is calculated to afford? If there be not, we must be at a loss to know why such a body was formed; certainly it could not be intended for our benefit, for it is rarely even seen by us:

Ask for what end the heavenly bodies shine?
Earth for whose use? Pride answers, "'Tis for mine:
——————suns to light me rise,
My footstool earth, my canopy the skies."
POPE.

But do these worlds display their beams, or guide
Their orbs, to serve thy use, to please thy pride?
Thyself but dust, thy stature but a span,
A moment thy duration; foolish man!
As well may the minutest emmet say,
That Caucasus was raised to pave his way:
The snail, that Lebanon's extended wood
Was destined only for his walk and food:
The vilest cockle, gaping on the coast
That rounds the ample seas, as well may boast,
The craggy rock projects above the sky,
That he in safety at its foot may lie;
And the whole ocean's confluent waters swell,
Only to quench his thirst, or move and blanch his shell:

PRIOR.

TUTOR. We now

the second planet

lar system. but

of them all.

Fairest of stars, last in

If better thou belong

Sure pledge of day, th

With thy bright circl

While day arises, th

Tutor. That planet is sixty-eight mil-
ons of miles from the sun, and she finishes
er journey in $224\frac{1}{4}$ days, consequently she
ust travel at the rate of 75,000 miles in a
our.

Charles. Venus is larger than Mercury,
dare say?

Tutor. Yes, she is nearly as large as
e earth, which she resembles also in other
spects, her diameter being about 7700
iles in length, and she has a rotation
bout her axis in 23 hours and 20 minutes.
'he quantity of light and heat which she
njoys from the sun, must be double that
hich is experienced by the inhabitants of
is globe.

James. Is there also a difference in her
easons, as there is here?

Tutor. Yes, in a much more considera-
le degree. The axis of Venus inclines
bout 75 degrees, but that of the earth in-
lines only $23\frac{1}{2}$ degrees, and as the variety
f the seasons in every planet depends on
he degree of the inclination of its axis, it

is evident that the seasons must vary with Venus than with us.

Charles. Venus appears to us larger at times than at others.

Tutor. She does; and this, with particulars, I will explain by means figure. Suppose s (Plate VII. Fig. to be the sun, T the earth in her orbit a, b, c, d, e, f, Venus in hers: now it is dent that when Venus is at a, between sun and earth, she would, if visible, a much larger than when she is at d in sition.

James. That is because she is so nearer in the former case than in the being in the situation a but 27 millio miles from the earth T, but at d she i millions of miles off.

Tutor. Now as Venus passes fro through b, c, to d, she may be observe means of a good telescope, to have al same phases as the moon has in pa from new to full: therefore when she d she is full, and is seen among the

n the beginning of Cancer: during
urney from d to e, she proceeds with
t motion in her orbit, and at e she
in Leo, and will appear to an inha-
of the earth, for a few days to be
ry, not seeming to change her place
the fixed stars, for she is coming
the earth in a direct line: but in
from e to f, though still with a di-
otion, yet to a spectator at T, her
will seem to be back again, or *retro-*
for she will seem to have gone back
to y; her path will appear retro-
ill she gets to c, when she will again
stationary, and afterwards from c
d from d to e it will be *direct* among
d stars.

les. When is Venus an evening,
en a morning star?

. She is an evening star all the
he appears *east* of the sun, and a
g star while she is seen *west* of him:

enus to the *westward* of the sun
'd her face, a golden plain of light
her larger round. Fair *morning* star

That leads on dawning day to yonder world
The *seat of Man.*

MALLET'S EXCURSION.

When she is at *a* she will be invisible, her dark side being towards us, unless she be exactly in the node, in which case she will pass over the sun's face like a little black spot.

James. Is that called the transit of Venus?

Tutor. It is; and it happens twice only in about one hundred and twenty years. By this phenomenon astronomers have been enabled to ascertain with great accuracy the distance of the earth from the sun; and having obtained this, the distances of the other planets are easily found. By the two transits which happened in 1761, and 1769, it was clearly demonstrated, that the mean distance of the earth from the sun was between ninety-five and ninety-six millions of miles.

Charles. How do you find the distances

of the other planets from the sun, by knowing that of the earth?*

Tutor. I will endeavour to make this plain to you. Kepler, a great astronomer, discovered that all the planets are subject to one general law, which is, that the *squares of their periodical times, are proportional to the cubes of their distances from the sun.*

James. What do you mean by the *periodical times?*

Tutor. I mean the times which the planets take in revolving round the sun; thus the periodical time of the earth is $365\frac{1}{4}$ days; that of Venus $224\frac{1}{4}$ days; that of Mercury 88 days.

Charles. How then would you find the distance of Mercury from the sun?

---

* The remainder of this conversation may be omitted by those young persons who are not ready in arithmetical operations. The author, however, knows from experience, that children may, at a very early age, be brought *to understand* these higher parts of arithmetic.

Tutor. By the rule of three: I w
say as the square of 365 days (the
which the earth takes in revolving a
the sun) is to the square of 88 days,
time in which Mercury revolves abou
sun,) so is the cube of 95 millions (the
tance in miles of the earth from the su
a fourth number.

James. And is that fourth nu
the distance in miles of Mercury from
sun?

Tutor. No: you must extract the
root of that number, and then you will
about thirty-seven millions of miles fo
answer, which is the true distance at w
Mercury revolves about the sun.

CONVERSATION XLI.

Of Mars.

TUTOR. Next to Venus is the earth and her satellite the moon, but of these sufficient notice has already been taken, and therefore we shall pass on to the planet Mars, which is known in the heavens by a dusky red appearance. Mars, together with Jupiter, Saturn, and the Herschel are called superior planets, because the orbit of the earth is enclosed by their orbits.

Charles. At what distance is Mars from the sun?

Tutor. About 144 millions of miles; the length of his year is equal to 687 of our days, and therefore he travels at the rate of more than 53 thousand miles in an hour:

his diurnal rotation on his axis is performed in 24 hours and 39 minutes, which makes his figure that of an oblate spheroid.

James. How is the diurnal motion of this planet discovered?

Tutor. By means of a very large spot which is seen distinctly on his face, when he is in that part of his orbit which is opposite to the sun and earth.

Charles. Is Mars as large as the earth?

Tutor. No; his diameter is only 41[illegible] miles in length, which is but little more than half the length of the earth's diameter. And owing to his distance from the sun he will not enjoy one half of the light and heat which we enjoy.

James. And yet, I believe, he has not the benefit of a moon.

Tutor. No moon has ever been discovered belonging either to Mercury, Venus, or Mars.

Charles. Do the superior planets exhibit [illegible] appearances of direct and retrograde [illegible] those of the inferior planets?

[illegible] They do: suppose s (Plate VIII.

Fig. 18.) the sun: *a*, *b*, *c*, *d*, *f*, *g*, *h*, the earth, in different parts of its orbit, and *m* Mars in his orbit. When the earth is at *a*, Mars will appear among the fixed stars at *x*: when by its annual motion the earth has arrived at *b*, *d*, and *f*, respectively, the planet Mars will appear in the heavens at *y*, *z*, and *w*: when the earth has advanced to *g*, Mars will appear stationary at *o*: to the earth in its journey from *g* to *h* the planet will seem to go backwards or retrograde in the heavens from *o* to *z*, and this retrograde motion will be apparent till the earth has arrived at *a*, when the planet will again appear stationary.

James. I perceive that Mars is retrograde when in *opposition*, and the same is, I suppose, applicable to the other superior planets; but the retrograde Motion of Mercury and Venus is when those planets are in *conjunction*.

Tutor. You are right: and you see the reason, I dare say, why the superior planets may be in the west in the morning when the sun rises in the east, and the reverse.

Charles. For when the earth
Mars may be at *n*, in which case
is between the sun and the planet: I
also that the planet Mars, and cons
the other superior planets, are muc
the earth at one time than at other

Tutor. The difference with re
Mars is no less than 190 millions
the whole length of the orbit of t
This will be a proper time to expl
is meant by the *Heliocentric* long
the planets referred to in the Ephe

James. Yes, I remember you
to explain this when you came to
the planets; I do not know the me
the word heliocentric.

Tutor. It is a term used to ex
place of any heavenly body as seen
sun; whereas the *geocentric* place of
is the position which it has when se
the earth.

Charles. Will you show us by
in what this difference consists?

Tutor. I will: let s (Plate VIII.
represents the place of the sun, b

a the earth in hers, and *c* Mars in
and the outermost circle will re-
ıe sphere of fixed stars. Now to a
on the earth *a*, Venus will appear
ıe fixed stars in the beginning of
but as viewed from the sun, she
seen beyond the middle of Leo.
e the *Geocentric* longitude of Ve-
be in Scorpio, but her *Heliocentric*
will be in Leo. Again, to a spec-
, the planet Mars at *c*, will appear
ıe fixed stars, towards the end of
of Pisces; but as viewed from the
ill be seen at the beginning of the
s: consequently the *geocentric* lon-
Mars is in Pisces; but his *helio-*
ngitude is in Aries.

hours, to make a revolution round the consequently he travels at the rate of than 28,000 miles in an hour.

This noble planet is accompanied four satellites which revolve about him different distances, and in different peri cal times, the *first* in about 1 day and hours: the *second* in 3 days 13 hours: *third* in 7 days 3 hours: and the *fourth* 16 days and 16 hours.

> Beyond the sphere of *Mars* in distant skies,
> Revolves the mighty magnitude of *Jove*
> With kingly state, the rival of the sun.
> About him round *four planetary moons*
> On earth with wonder all night long beheld
> Moon above moon, his fair attendants dance.
>
> MALLET'S EXCURSION.

Charles. And are these satellites, like our moon, subject to be eclipsed?

Tutor. They are; and their eclipses are of considerable importance to astronomers, in ascertaining with accuracy the longitude of different places on the earth.

By means of the eclipses of Jupiter's satellities, a method has been also obtained of demonstrating that the motion of light is *pro-*

sive, and not *instantaneous*, as was once
osed. Hence it is found, that the ve-
y of light is nearly 11,000 times grea-
han the velocity of the earth in its or-
ınd more than a million of times grea-
han that of a ball issuing from a cannon.
discovery is alluded to by the last
ioned poet: speaking of an observer of
clipses and Jupiter's satellites, he says,

By these observ'd, the *rapid progress finds*
Of *light* itself; how swift the headlong ray
Shoot's from the sun's height through unbounded
space.
At once enlight'ning air, and earth, and heaven.

s of light come from the sun to the
ı in 8 minutes, that is at the rate of 12
ons of miles in a minute nearly.

CONVERSATION XLIII.

Of Saturn.

TUTOR. We are now arrived at Saturn in our descriptions, which, till within these twenty years, was esteemed the most remote planet of the solar system.

Charles. How is he distinguished in the heavens?

Tutor. He shines with a pale dead light, very unlike the brilliant Jupiter, yet his magnitude seems to vie with that of Jupiter himself. The diameter of Saturn is nearly 80 thousand miles in length: his distance from the sun is more than 900 millions of miles, and he performs his journey ... that luminary in a little less than 30

of our years, consequently he must travel at a rate not much short of 21,000 miles an hour.

James. His great distance from the sun must render an abode on Saturn extremely cold and dark too, in comparison of what we experience here.

Tutor. His distance from the sun being between 9 and 10 times greater than that of the earth, he must enjoy about 90 times less light and heat; it has nevertheless been calculated that the light of the sun at Saturn is 500 times greater than that we enjoy from our *full moon*.

Charles. The day-light at Saturn, then, cannot be very contemptible: I should hardly have thought that the light of the sun here was 500 times greater than that experienced from a full moon.

Tutor. So much greater is our meridian light than this, that during the sun's absence behind a cloud, when the light is much less strong than when we behold him in all his glorious splendour, it is reckoned that our

day-light is 90,000 times greater than the light of the moon at its full.

James. But Saturn has several moons, I believe?

Tutor. He is attended by *seven* satellites or moons, whose periodical times differ very much; the one nearest to him performs a revolution round the primary planet in 22 hours and a half; and that which is most remote takes 79 days and 7 hours for his monthly journey: this last satellite is known to turn on its axis, and in its rotation is subject to the same law which our moon obeys, that is, it revolves on its axis in the same time in which it revolves about the planet.

Besides the seven moons, Saturn is encompassed with two broad rings which are probably of considerable importance in reflecting the light of the sun to that planet; the breadth of the inner ring is 20,000 miles, that of the outer ring 7200 miles, and the vacant space between the two rings is 2839 miles. These rings give Saturn a very different appearance to any of the other planets. Plate VIII. Fig. 20, is a representa-

tion of Saturn as seen through a good telescope. On the supposition that Saturn was the most remote planet of our system, he is thus described by Mallet in his Excursion:

Last, outmost Saturn walks his frontier round
The boundary of worlds, with his pale moons,
Faint glimmering through the gloom which night
has thrown
Deep-dyed and dead o'er this chill globe forlorn:
An endless desert, were extreme of cold
Eternal sits, as in his native seat,
On wintery hills of never-thawing ice.
Such *Saturn's* earth; and even here the sight
Amid these doleful scenes, new matter finds
Of wonder and delight! a mighty *ring!*

Charles. Is it known whether Saturn turns on its axis?

Tutor. According to Dr. Herschel (it has a rotation about its axis in 12 hours $13\frac{1}{4}$ minutes: this he computed from the equatorial diameter being longer than the polar diameter in the proportion of 11 to 10. Dr. Herschel has also discovered that the ring, just mentioned, revolves about the planet in *10 hours* and a half.

CONVERSATION XXIII.

Of The Herschel Planet.

TUTOR. We have but one other planet to describe, that is the Herschel?

James. Was it discovered Dr. Herschel?

Tutor. It was, on the 13th of March, 1781, and therefore by astronomers in general it is denominated the Herschel planet; though by Doctor himself it was named the Georgium Sidus, or Georgian Star, in honour of his present majesty George the Third, who has for many years been a liberal patron to this great and most indefatigable astronomer.

Charles. I do not think that I have ever seen this planet.

Tutor. Its apparent diameter is too small to be discerned readily by the naked eye, but it may be easily discovered in a clear night, when it is above the horizon, by means of a good telescope, its situation being previously known from the Ephemeris.

James. Is it owing to the smallness of this planet, or to its great distance from the sun, that we cannot see it with the naked eye?

Tutor. Both these causes are combined: in comparison of Jupiter and Saturn it is small, his diameter being less than thirty-five thousand miles in length; and his distance from the sun is estimated at more than one thousand eight hundred millions of miles from that luminary, around which, however, he performs his journey in eighty-two of our years, consequently he must travel at the rate of 16,000 miles an hour.

Charles. But if this planet has been

discovered on twenty-two years, how i
known that it will complete its revoluti
eighty-two years?

Tutor. By a long series of observa
it was found to move with such a velo
as would carry it round the heavens in
period. Moreover, when it was first
covered, it was in Gemini, and in A
1803, it had advanced in the 11° of I
more than a fourth part of its jour
and now in June, 1809, it is in the c
of Scorpio.

James. How many moons has the
schel?

Tutor. He is attended by six sat
or moons, of which, the one near
the planet performs his revolution
the primary in five days and twenty
hours, but that which is the most r
from him takes 107 days and 16 hou
his journey.

Charles. Is there any idea form
to the light and heat enjoyed by thi
net?

Tutor. His distance from the

nineteen times greater than that of the earth, consequently since the square of 19 is 361, the light and heat experienced by the inhabitants of that planet must be 361 times less than *we* derive from the rays of the sun.

The proportion of light enjoyed by the Herschel has been estimated at about equal to the effect of two hundred and forty-nine of our full moons.

CONVERSATION XLV.

Of Comets.

TUTOR. Besides the seven primary planets, and the eighteen secondary ones or satellites, which we have been describing, there are other bodies belonging to the solar system, called comets, to which Thomson in his Summer beautifully alludes:

——————Amid the radiant orbs
That more than deck, that animate the sky,
The life-infusing suns of other worlds;
Lo! from the dread immensity of space
Returning with accelerated course
The rushing *comet* to the sun descends.

And as he sinks below the shading earth,
With awful train projected o'er the heavens,
The guilty nations tremble.

SUMMER, line 1702.

Charles. Do comets resemble the planets in any respects?

Tutor. Like them they are supposed to revolve about the sun in elliptical orbits, and to describe equal areas in equal times; but they do not appear to be adapted for the habitation of animated beings, owing to the great degrees of heat and cold to which, in their course, they must be subjected.

The comet seen by Sir Isaac Newton, in the year 1680, was observed to approach so near the sun, that its heat was estimated by that great man, to be 2000 times greater than that of red-hot iron.

James. It must have been a very solid body to have endured such a heat without being entirely dissipated.

air, will scarcely lose all its heat in a
and it is said, that a globe of red-h
as large as our earth, would scarc
in 50,000 years. See Enfield's I
of Natural Philosophy, p. 296, sec
tion.

Charles. Are the periodical time
comets known?

Tutor. Not with any degree of c
it was supposed that the periods of
them had been distinctly ascertaine
first of these appeared in the yea
1607, and 1682, and it was expecte
turn every 75th year; and one w
had been predicted by Dr. Halley,

this the astronomers of the present day have been disappointed.

The *third* was that which appeared in 1680, and its period being estimated at 575 years cannot, upon that supposition, return until the year 2255. This last comet at its *greatest* distance is eleven thousand two hundred millions of miles from the sun, and its *least* distance from the sun's centre was but four hundred and ninety thousand miles; in this part of its orbit it travelled at the rate of eight hundred an eighty thousand miles, in an hour.

James. Do all bodies move faster or slower in proportion as they are nearer to, or more distant from their centre of motion?

Tutor. They do, for if you look back upon the last six or seven lectures, you will see that the Herschel, which is the most remote planet in the solar system, travels at the rate of 16,000 miles an hour; Saturn the next nearer in the order 21,000 miles; Jupiter 28,000 miles; Mars 53,000 miles;

the earth 65,000 miles; Venus 75,000 miles; and Mercury at the rate of 105,000 miles in an hour. But here we come to a comet whose progressive motion in that part of its orbit which is nearest to the sun, is more than equal to eight times the velocity of Mercury.

Charles. Were not comets formerly dreaded, as awful prodigies intended to alarm the world?

Tutor. Comets are frequently accompanied with a luminous train called the tail, which is supposed to be nothing more than vapour rising from the body in a line opposite to the sun, but which, to uninformed people, has been a source of terror and dismay, and to this opinion many of our poets have alluded:

——————Where the *train*
Of comets wander in eccentric ways
With infinite excursion through th' immense
Of ether, traversing from sky to sky
Ten thousand regions, in their winding road

length to trace imagination fails;
their paths——
istant orbs with wonder and amaze
ieir approach, and night by night alarm'd
readed progress watch, as of a foe
march is ever fatal, in whose train
and war, and desolating plague,
his pale horse rides, the ministers
y Heaven to scourge offending worlds!

MALLET'S EXCURSION

CONVERSATION XLVI.

Of the Sun.

TUTOR. Having given you a particular description of the planets which revolve about the sun, and also of the satellites which travel round the primary planets as central bodies, while they are carried at the same time with these bodies round the sun, we shall conclude our account of the solar system by taking some notice of the sun himself,

> Informer of the planetary train,
> Without whose quick'ning glance their cumbrous orbs
> Were brute unlovely mass, inert and dead,
> And not, as now, the green abodes of life.
>
> THOMSON'S AUTUMN, line 1086.

James. You told us a few days ago, that the sun has a rotation on its axis, how is that known?

Tutor. By the spots on his surface it is known that he completes a revolution from west to east on his axis in about twenty-five days, two days less than his *apparent* revolution, in consequence of the earth's motion in her orbit, in the same direction.

Charles. Is the figure of the sun globular?

Tutor. No; the motion about its axis renders it spheriodical, having its diameter at the equator longer than that which passes through the poles.

The sun's diameter is equal to 100 diameters of the earth, and therefore his bulk must be a million of times greater than that of the earth, but the density of the matter of which it is composed is four times less than the density of our globe.

We have already seen that by the attraction of the sun, the planets are retained in their orbits, and that to him they are indebted for light, heat and motion:

Fairest of Beings! first created light:
Prime cause of beauty! for from thee alone
The sparkling gem, the vegetable race,
The nobler worlds that live and breathe their
charms,
The lovely hues peculiar to each tribe,
From thy unfailing source of splendour draw!
In thy pure shine, with transport I survey
This firmament, and these her rolling worlds
Their magnitudes and motions.—

MALLET'S EXCURSION.

CONVERSATION XLVII.

Of the Fixed Stars.

TUTOR. We will now put an end to our astronomical conversations by referring again to the fixed stars, which like our sun shine by their own light.

Charles. Is it then certain that the fixed stars are of themselves luminous bodies; and that the planets borrow their light from the sun?

Tutor. By the help of telescopes it is known that Mercury, Venus, and Mars shine by a borrowed light, for like the moon, they are observed to have different phases according as they are differently si-

tuated with regard to the sun. The immense distances of Jupiter, Saturn, and the Herschel planet, do not allow the difference beween the perfect and imperfect illumination of their discs or phases to be perceptible.

Now the distance of the fixed stars from the earth is so great, that reflected light would be much too weak ever to reach the eye of an observer here.

James. Is this distance ascertained with any degree of precision?

Tutor. It is not: but it is known with certainty to be so great, that the whole length of the earth's orbit, viz. 190 million of miles, is but a point in comparison of it; and hence it is inferred that the distance of the nearest fixed star, cannot be less than a hundred thousand times the length of the earth's orbit;* that is, a hundred thousand times 190 millions of miles,

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* See Dr. Enfield's Institutes of Natural Philosophy, p. 347. Second Edition, 1799.

or 19,000,000,000,000 miles: this distance being immensely great, the best method of forming some clear conception of it, is to compare it with the velocity of some moving body, by which it may be measured. The swiftest motion with which we are acquainted is that of light, which, as we have seen, is at the rate of twelve millions of miles in a minute: and yet light would be about three years in passing from the nearest fixed star to the earth.

A cannon-ball which may be made to move at the rate of twenty miles in a minute, would be 1800 thousand years in traversing the distance. Sound, the velocity of which is thirteen miles in a minute, would be more than two million seven hundred thousand years in passing from the star to the earth. So that if it were possible for the inhabitants of the earth, to see the light;—to hear the sound;—and to receive the ball of a cannon discharged at the nearest fixed star; they would not perceive the *light of its* explosion for three years after

it had been fired; nor receive the ball till 1820 thousand years had elapsed; nor hear the report for two millions and seven hundred thousand years after the explosion.

Charles. Are the fixed stars at different distances from the earth?

Tutor. Their magnitudes, as you know, appear to be different from one another, which difference may arise either from a diversity in their real magnitudes, or in their distances, or from both these causes acting conjointly. It is the opinion of Dr. Herschel that the different apparent magnitudes of the stars arise from the different distances at which they are situated, and therefore he concludes that stars of the seventh magnitude, are at seven times the distance from us than those of the first magnitude are.

By the assistance of his telescopes he is able to discover stars at 497 times the distance of *Sirius* the Dog-star: from which he infers that with more powerful instruments he should be able to discover stars at still greater distances.

nes. I recollect that you told us once, had been supposed by some astrono- that there might be fixed stars at so a distance from us, that the rays of light had not yet reached the earth, h they had been travelling at the of twelve millions of miles in a mi- from the first creation to the present

or. I did; it was one of the sublime ations of the celebrated Huygens. alley has also advanced what, he says, to be a metaphysical paradox, viz. he number of fixed stars must be more inite, and some of them at a greater finite distance from others; and Mr. on has justly observed, that this ht is far from being extravagant, we consider that the universe is the of infinite power, promoted by infi- oodness, and having an infinite space rt itself in; so that our imagination t no bounds to it.

distant some of the nocturnal suns!
stant, says the sage, 'twere not absurd

To doubt, if beams set out at Nature's birth,
Are yet arriv'd at this so foreign world;
Though nothing half so rapid as their flight.

YOUNG.

Charles. What can be the use of these fixed stars?—not to enlighten the earth, for a single additional moon would give us much more light than them all, especially if it were so contrived as to afford us its assistance at those intervals when our present moon is below the horizon.

Tutor. You are right: they could not have been created for our use, since thousands, and even millions, are never seen but by the assistance of glasses, to which but few of our race have access. Your minds indeed are too enlightened to imagine, like children unaccustomed to reflection, that all things were created for the enjoyment of man. The earth on which we live is but one of seven primary planets circulating perpetually round the sun as a centre, and with these are connected eighteen secondary planets or moons, all of

which are probably teaming with living beings capable, though in different ways, of enjoying the bounties of the great First Cause.

The fixed stars then are probably suns, which, like our sun, serve to enlighten, warm, and sustain other systems of planets and their dependent satellites.

James. Would our sun appear as a fixed star at any great distance?

Tutor. It certainly would: and Dr. Herschel thinks there is no doubt, but that it is one of the heavenly bodies belonging to that tract of the heavens known by the name of the *Milky Way*.

Charles. I know the milky way in the heavens, but I little thought that I had any concern with it otherwise than as an observer.

Tutor. The milky way consists of fixed stars, too small to be discerned with the naked eye; and if our sun be one of them, the earth and other planets are closely connected with this part of the heavens.

But, Gentlemen, it is time that we take our leave of this subject for the present. For your attention to those instructions which, on this and other topics, I have been able to communicate, accept my best thanks. For your future welfare and happiness, my heart is deeply interested. You will not, I flatter myself, very soon forget that connexion which has subsisted between us for a long course of years. From my mind the remembrance of your kindness can never be obliterated. Permit me, then as a testimony of my gratitude and sincere affection, to recommend to your future attention the works of nature and creation, by a careful investigation of which you will necessarily be led to the contemplation and love of the God of Nature.

Your knowledge, young as you yet are, of the fundamental principles of Geometry and Algebra, is such as to render scientific pursuits easy and pleasant. And your understandings are not more capaple of entering into the sublime speculations of science, than your hearts are adapted to r

ceive and cherish those impressions of gratitude, which are the natural consequences of enlarged and comprehensive views of the being and perfections of the Deity. In all your studies and pursuits, then, never forget, that

> ——————you cannot go
> Where UNIVERSAL LOVE not smiles around,
> Sustaining all yon orbs, and all their sons;
> From seeming evil still educing good,
> And better thence again, and better still,
> In infinite progression.
>
> THOMSON.

END OF VOLUME I.

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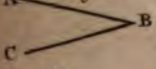

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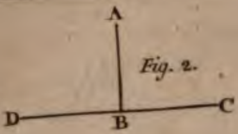

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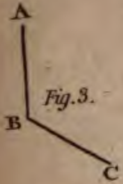

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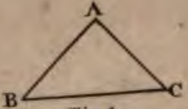

Fig. 4.

Fig. 5.

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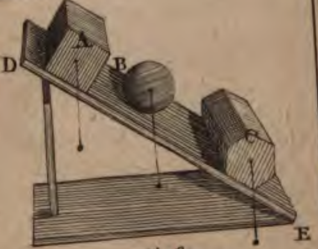

Fig. 8.

J. Bower sc.


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Fig.15.
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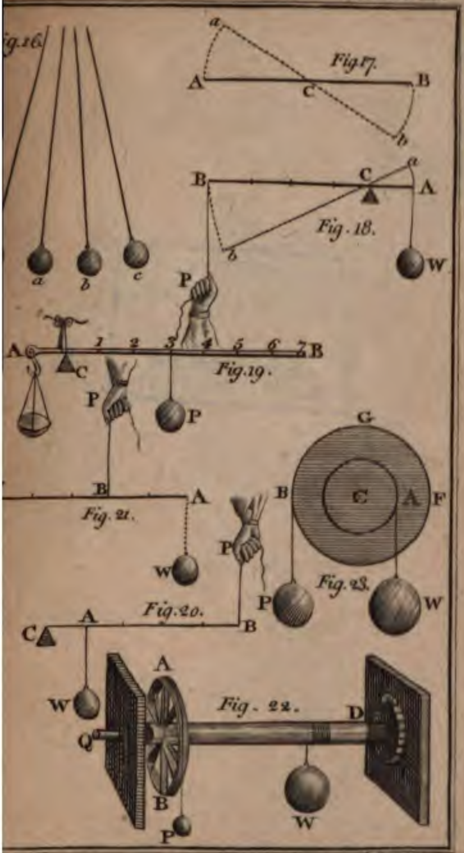
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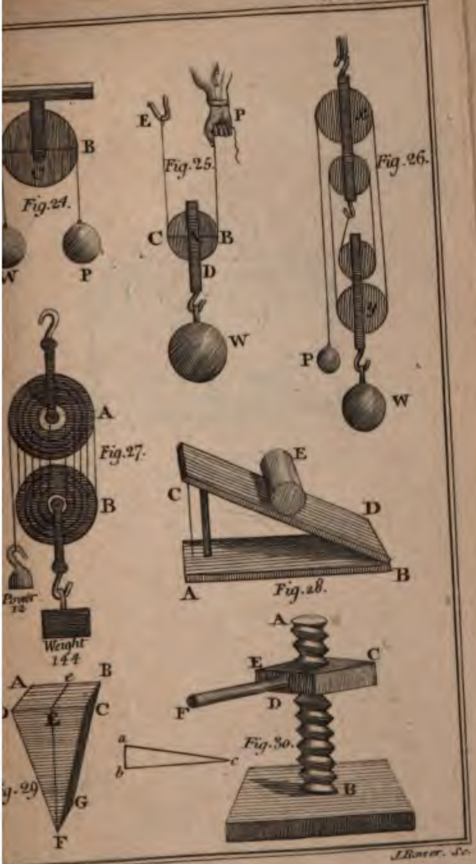
J.Bow sc.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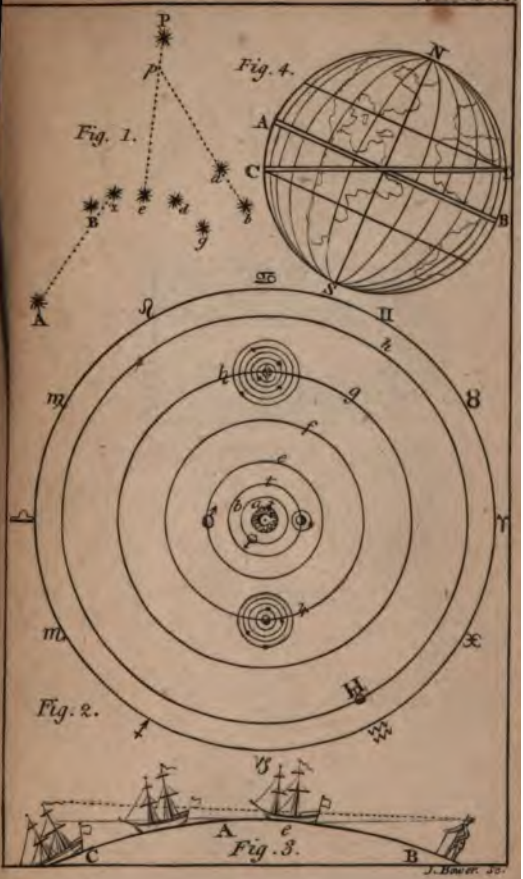
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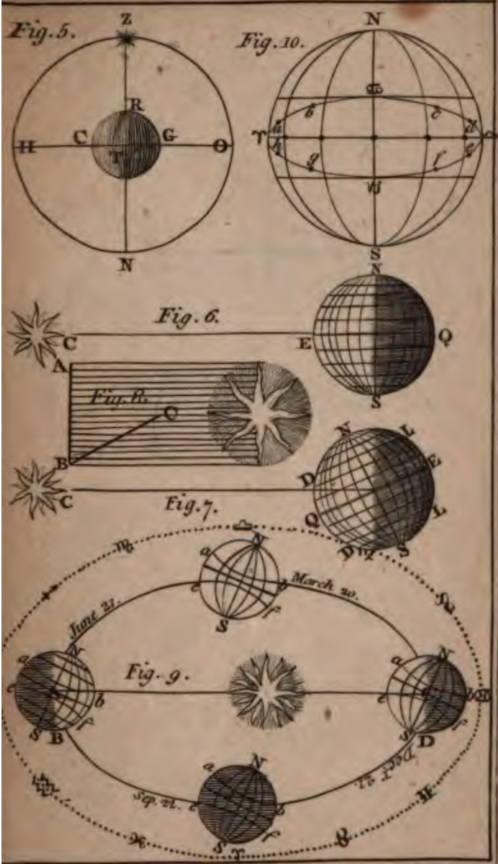

Fig. 5.
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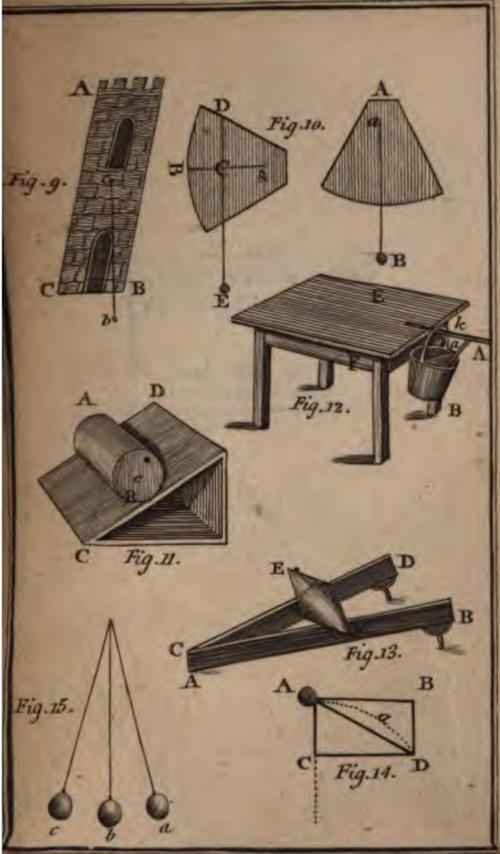

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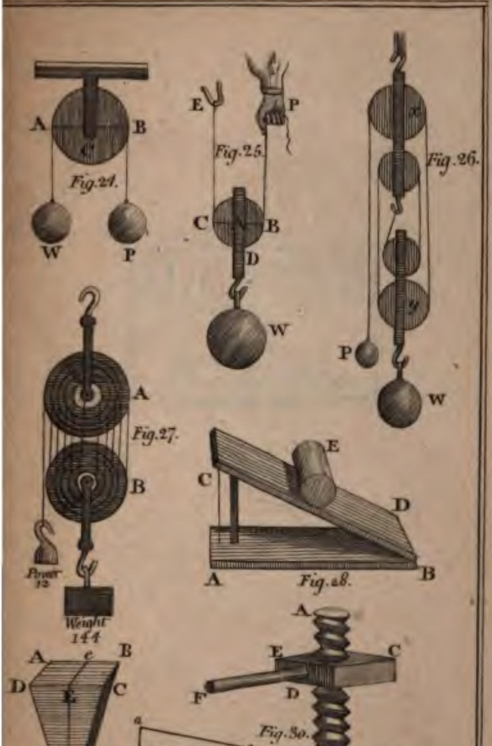
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J. Rowe. Sc.

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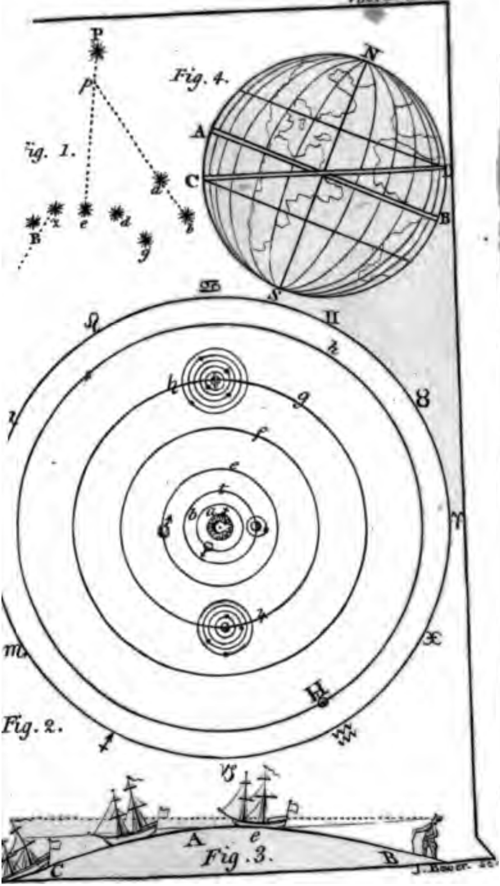

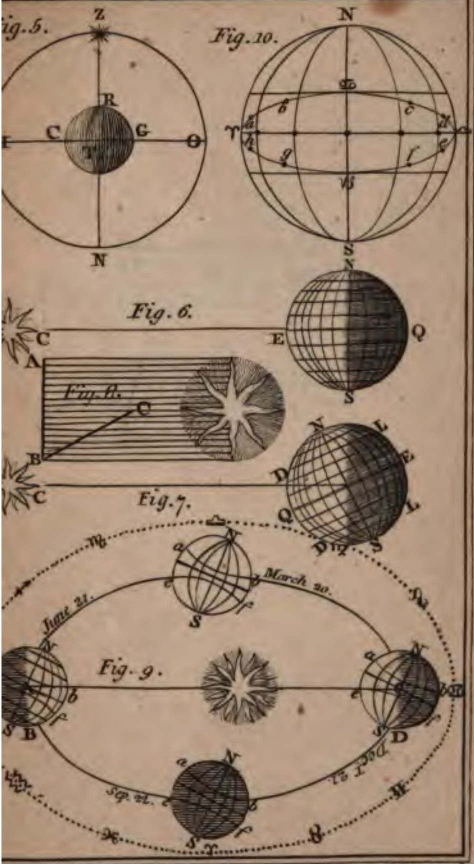

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Fig. 20.

Fig. 19.

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